BRITISH JOURNAL OF HOSPITAL MEDICINE

REVIEW

Addressing Gender Inequality in Sports: Mechanisms and Strategies for Preventing Soft Tissue Injury in Elite Female Athletes

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Abstract

As female participation in sports, traditionally dominated by males continues to grow, a notable trend has emerged: female athletes are disproportionately affected by soft tissue injuries, with anterior cruciate ligament (ACL) injury having an incidence rate up to 9 times more frequently than in their male counterparts. The burden of soft tissue injuries in female athletes such as hamstring injury, ankle sprain, and ACL injury is exacerbated by the underrepresentation of elite female athletes in sports medicine, and therefore suboptimal prevention and rehabilitative methods. This manuscript delves into the anatomical, hormonal, and training-related factors that contribute to this disparity. It examines common injury patterns including knee, ankle, and hamstring injuries, elucidating the pathophysiological mechanisms involved. The severe impact of these injuries can jeopardise the careers of elite sportswomen and prompt the need for a paradigm shift in sports medicine. This paper provides a current overview of injury management and discusses essential changes in prevention and rehabilitation strategies to improve outcomes for female athletes. By examining the existing body of knowledge, this review focuses on proposing future interventions and prevention strategies that are tailored to the unique needs of female athletes.

Key words: sports medicine; orthopedics; soft tissue injuries; anterior cruciate ligament injuries; ankle injury; hamstring muscles

Submitted: 24 December 2024 Revised: 5 February 2025 Accepted: 25 February 2025

Introduction

The participation of women in previously male-dominated sports has surged in recent years, both at the elite and recreational levels (Talia et al, 2024). While this progress is encouraging, it is overshadowed by a concerning rise in soft tissue injuries among female athletes compared to males. There is a lack of understanding behind this disparity and therefore, a lack of targeted, female-specific strategies for mitigation. The most common injuries seen amongst elite female footballers during the 2019 Federation Internationale de Football Association (FIFA) World Cup were reported to be muscle strains, ankle sprains, and anterior cruciate ligament (ACL) injuries (Saltzman et al, 2023) (Tables 1 and 2). For an elite sportswoman,

How to cite this article:
Powling AS, Lisacek-Kiosoglous AB, Takenoshita M, Fontalis A, Haddad FS. Addressing Gender Inequality in Sports: Mechanisms and Strategies for Preventing Soft Tissue Injury in Elite Female Athletes. Br J Hosp Med. 2025. https://doi.org/10.12968/hmed.2024.1060

these injuries are career-jeopardising. A recent prospective study looking at 15 elite women's football teams in Europe reported a median of 292 days lost from ACL injury, whilst injury burden was 38 days lost per 1000 hours (Hallén et al, 2024). Similarly, hamstring injury (HSI) burden remains high, causing 12%–16% of all time-loss injuries in women's elite football, prompting definitive strategies to assist athletes returning to pre-injury level (Ekstrand et al, 2023).

Suggested predispositions for increased soft tissue injuries in women include hormonal and anatomical variation, and extrinsic factors such as a lack of robust preventative training regimes compared to male athletes (Fig. 1) (Ekstrand et al, 2023; Gianakos et al, 2022; Mancino et al, 2024; Miyazaki and Maeda, 2022). Research often lacks gender specificity due to limitations such as data availability, inherent sex biases, and funding, which could collectively skew the representation of evidence. A systematic review found that a large majority of studies focus on male athletes compared to female athletes, 70.7% and 8.8% respectively (Paul et al, 2023). It is important for researchers to maintain gender balance during study inclusion, rather than favouring male participants, even in co-ed sports (Paul et al, 2023). The sought-after increase of female sport professionalism is curbed by lack of funding available, leading to insufficient training time, inadequate training resources, absence of professional medical staff, and lack of qualified strength and conditioning coaches. It has been reported that female athletes have less on-field access to athletic trainers following sports-related concussions compared to male athletes, which questions the resource equity available to female athletes (Prosak et al, 2024). A series of interviews with female rugby union players elucidated that male athletes get priority for resources. This included training pitches and expert support, particularly in time of injury. Physiotherapy allocation and medical support were considered the second priority for female players after male players, and inevitably impacted tackle-safety techniques and general physical health (Dane et al, 2024). A study among elite athletes in Germany reported that there were significant gender wage gaps between male and female athletes, with males earning more (Wicker et al, 2023). Media coverage also has a role in the sociocultural norms of female elite sport. Whilst previously denied media attention, sportswomen now have larger audiences including 1.745 billion television viewers at the 2019 FIFA Women's World Cup. Despite the progress, gender disparities in the media may affect the equality of financial support from sponsors and equal pay distribution (Rowe and Silva, 2023).

Career-jeopardising soft tissue injuries not only cause physical setbacks, but also psychological distress. Fewer females return to their pre-injury form due to lower risk tolerance and psychological aversion (Siegel, 2024). A systematic review reported an acute depressive state up to 6 weeks post-surgery for many athletes, with anxiety and fear surrounding the possibility of re-rupture after ACL reconstruction (ACLR) (Ramos Pastrana et al, 2024). For females with a higher incidence of soft tissue injury, this is even more crucial to address, given that patients returning to sport (RTS) before being psychologically ready face higher re-rupture rates (Ramos Pastrana et al, 2024). A comprehensive review by Basu et al (2022) reported that psychological stress can delay wound healing through mechanisms that include

Fig. 1. Most commonly identified risk factors for elite female athletes to sustain soft tissue injuries. (The figure was created via Canva, Canva Inc., Sydney, Australia).

increased cortisol levels, which may suppress the pro-inflammatory cytokines necessary for matrix regeneration and angiogenesis. It is evident that current standard rehabilitation protocols with objective parameters are insufficient to accurately determine when a female athlete should RTS, given there may be psychological risk aversion to consider (Siegel, 2024). It may be reasonable for athletes to be offered cognitive behavioural therapies to support them with psychologically driven kinesiophobia post-ACLR (Brewer et al, 2022), Coronado et al (2020) demonstrated via an open pilot study the potential use of a cognitive-behavioural-based physical therapy with promising direction. Furthermore, menstrual dysfunction, low bone mineral density, and low energy availability in physically active individuals have been referred to as the female triad phenomenon and often linked with disordered eating. This mismatch between calories consumed and metabolic demand leads to a state of relative energy deficiency, theorised to have a strong association with sports injuries (Edama et al, 2021).

Current literature lacks robust, female-specific preventive training programmes, as well as clear guidance on tailored rehabilitation following soft tissue injuries. The differing mechanisms of injury and risk factors between male and female athletes remain largely unexplored areas within sports exercise medicine. This paper aims to provide clinicians with a contemporary overview of the most common soft tissue injuries in elite female athletes, exploring the aetiology and clinical outcomes of preventive and rehabilitative strategies. It also proposes future directions for optimising injury management in female athletes.

Common Soft Tissue Injury in Elite Female Athletes

ACL Injuries

An injury to the ACL occurs in 1 out of 29 sportswomen, compared to just 1 out of 50 sportsmen, and leads to significant lost game time (Montalvo et al, 2019). The Australian Football League Women's saw up to 9.2 times higher incidence of ACL injuries compared to the men's Australian Football League across 2 seasons, reported as 4.31 vs 0.7 and 6.47 vs 0.7 per 1000 player hours in 2017 and 2018 respectively (Fox et al, 2020). It is hypothesized that the biophysiological explanation of female ACL injury is a misrepresentation of a wider cause, perpetuating damaging gender stereotypes in sports. A recent systematic review reported that almost 70% of female athletes can RTS at approximately 10.8 months post-ACLR but this figure trails behind an earlier RTS for males (Figueroa et al, 2024). Moreover, a recent systematic review and meta-analysis found females had a 23%–25% lower odds rate of RTS 1-year post-ACLR, as well as experiencing suboptimal clinical outcomes when assessed on the knee injury and osteoarthritis outcome score (KOOS) (Bruder et al, 2023). Sports posing a high risk for non-contact ACL injury among females include gymnastics, football, and basketball (Table 2).

Risk Factors for ACL Injury

Widely reported intrinsic risk factors for ACL injury in females include anatomical, hormonal, and biomechanical aspects. One anatomical consideration is the smaller femoral notch in females, which may predispose to ACL impingement (Mancino et al, 2024). Additionally, the smaller size of the ACL might reduce its tensile strength, increasing susceptibility to damage (Mahajan et al, 2015). Myrick et al (2019) found that in female soccer athletes, average ACL size increased significantly from preseason to postseason. Local oedema also increased but not significantly. This was attributed to repeated microscopic tears and subsequent states of healing. These findings raise questions about whether such volumetric increases reflect ACL remodelling and functional changes that elevate injury risk (Myrick et al, 2019). However, as laxity was not measured in this study, this hypothesis remains speculative.

The menstrual cycle has attracted particular attention with oestrogen levels linked to ligament laxity. If ligaments are lax, there may be increased tibiofemoral motion whilst the ACL is under extreme tensions during the typical non-contact

Table 1. Summary of most recent elite female HSI epidemiology, prevention and postoperative rehabilitation protocol studies.

Author	NHMRC level of evidence	Study characteristics	Results
Epidemiology/Incidence			
Hardaker et al, 2024	I	Sport: All participants considered athletes. Population: Healthy, sporty participants up to 65 years old. Intervention: Standardised injury data collection intervention. Comparator: Analysed/reported by sex. Outcome: Injury rate, incidence, rate ratio, odds ratio, proportion ratios. Study design: Systematic review and meta-analysis.	Sample: 180 studies. Main findings: Relative to males, female athletes exhibited: higher risk of knee injuries (rate ratio: 2.7), higher risk of foot/ankle injuries (rate ratio: 1.25) and lower risk of hip and groin injuries. Authors advocated for optimisation of bone strength during female adolescence and earlier neuromuscular training in female athletes.
Hallén et al, 2024	III	Sport: Football (soccer). Population: Elite female athletes. Intervention: Injuries (any). Comparator: 2018/2019 to 2021/2022 seasons. Outcome: Time-injury loss epidemiology and characteristics of elite female athletes. Study design: Prospective study.	Sample: 596 players (1527 injuries) from 15 elite women's teams in Europe, over 44 seasons. Main findings: Injury incidence mean = 6.7 injuries per 1000 hours (nearly 4 fold higher incidence in match play versus training). Hamstring and quadriceps were the most frequent injuries, 12% and 11%, respectively. An elite women's football team may experience 35 time-loss injuries per season, or 1.5 injuries per player.

Table 1. Continued.

Author	NHMRC level of evidence	Study characteristics	Results
Mullins et al, 2022	I	Sport: Field sports-predominantly football (soccer). Population: Female athletes. Intervention: Injuries (medically diagnosed). Comparator: Other. Outcome: Incidence of HSI. Study design: Systematic review and meta-analysis.	Sample: 12 studies, n = 1070. Main findings: Moderate evidence that HSI incidence was 0.6 injuries per 1000 exposure hours.
Prevention			
Zouita et al, 2023	I	Sports: Athletics, cycling, basketball, handball, volleyball, softball, soccer, field hockey, swimming, cross-country skiing, water polo. Population: Elite female athletes. Intervention: Long-term resistance training studies or combinations of resistance training with other strength-based exercise. Comparator: Active and/or passive controls. Outcome: Measured muscle strength, proxies of muscle power, muscle morphology, and body composition. Study design: Systematic review.	Sample: n = 33 studies. Main findings: 24 studies used single-mode resistance training or plyometric training programmes, and 9 studies used combined training programmes. In elite female athletes, resistance training or combination training leads to significant increases in power, strength, speed, and jump performance, irrespective of the programming parameters.

Table 1. Continued.

Author	NHMRC level of evidence	Study characteristics	Results
Ruiz-Rios et al, 2024	I	Sports: Football (soccer). Population: World Class, Elite/International Level/National Level female soccer players worldwide. Intervention: All interventions must be related to football (Soccer). Comparator: With or without controls. Outcome: Physical and functional injury screening characteristics. Study design: Experimental and observational studies.	Sample: n = 10 studies. Main findings: Effective injury prevention could be enhanced by incorporating force–velocity assessments, field tests for aerobic capacity and power, lower limb range of motion, and core strength assessments. Seasonal variations in conditioning, with performance typically declining during transition periods, necessitating tailored off-season maintenance are reported. There is a need for clear and consistent injury risk assessments, which vary in the literature. Unilateral counter movement jumps are commonly used; however, inconsistencies in reporting definitions of the dominant leg and ROM impact the evaluations of injury risk.
Ekstrand et al, 2023	III	Sport: Football (soccer). Population: Elite female athletes. Study design: Questionnaire to Chief Medical Officers of clubs that participated in the Women's Elite Club Injury Study season 2020/2021. The aim was to explore the importance of hamstring injury risk factors, and to also compare if these perceived risk factors differed between teams with varying HSI rates.	Sample: 11 Chief Medical Officers replied to the survey. Main findings: 12 risk factors were considered extrinsic and 9 were intrinsic/player factors. The risk factors with the highest average importance include: "lack of communication between medical staff and coaching staff" and "load on players", followed by "lack of regular exposure to high-speed football actions during training" and "playing matches 2–3 times a week". The group with higher HSI's perceived these risk factors as more important.

Table 1. Continued.

Author	NHMRC level of evidence	Study characteristics	Results
Post injury rehabilitation			
Pollock et al, 2022	III	Sports: Athletics. Population: Elite athletes on Olympic World Class Programmes. Intervention: Rehabilitation followed the British Athletics hamstring injury management approach. Outcome: Time to return to sport. Study design: Prospective design.	Sample: 70 HSI's – 46 athletes. Main findings: 87% of injuries occurred in the Sprint/Power group and 13% of injuries occurred in the Endurance athlete group. Time to return to full training was 18.6 days for all participants. Muscle oedema, tendon injury, and loss of tendon tension were linked to return to sport length. Length of tendon injury, in the intra-tendon classes, was not associated with return to sport duration.
Macdonald et al, 2019	VII	Sport: Athletics. Guidelines linking diagnosis utilising The British Athletics Muscle Injury Classification with a specific rehabilitation programme. The aim of this review was to explore each class of injury: clinical presentation, physiology, and rehabilitation. Study design: Review.	Main findings: Principle 1: Provide an accurate injury classification. Principle 2: Incorporate collaborative expertise. Principle 3: Shared decision-making. Principle 4: Neuromuscular training. Principle 5: Prescribe strength exercises to achieve a specific goal. 1. Eccentric training. 2. Increase fascicle length. 3. Isometric training. 4. Develop fatigue resistance. 5. Overcoming selective muscle inhibition. Principle 6: Target contributing injury risk factors.

NHMRC, the National Health and Medical Research Council; HSI, hamstring injury; ROM, range of motion.

Table 2. Summary of most recent elite female ACL injury epidemiology, prevention and postoperative rehabilitation protocol studies.

Author	NHMRC level of evidence	Study characteristics	Results
Epidemiology/Incidence			
Montalvo et al, 2019	I	Sport: Any sport. Population: Any age. Intervention/diagnosis: ACL injury in female athletes. Comparator: ACL injury male athletes. Outcome: ACL injury outcomes. Study design: Systematic review.	Sample: 58 studies. Main findings: IR of ACL injury in female athletes was 1.5/10,000 athlete exposures. IP in female athletes was 1 out of 29 athletes. IR and IP of ACL injury in male athletes was 0.9/10,000 athlete exposures, and 1 out of 50 athletes respectively. Female athletes had a higher relative risk (RR) of 1.5 which was higher than males.
Prevention			
Al Attar et al, 2022	I	Sport: Football (soccer). Population: Female and male football players. Intervention: Plyometric exercises incorporated. Comparator: Non-plyometric based warmups. Outcome: Number of ACL injuries, ACL injury rate and exposure hours. Study design: Systematic review.	Sample: 9 studies, 4 female-only, 2 female and male, 3 male-only participants, n = 14,394. Main findings: Plyometric exercises decreased ACL injury risk by 60% per 1000 hours of exposure. 50% reduction in ACL injuries in the studies of females.
Crossley et al, 2020	I	Sport: Football (soccer). Population: Female football players, any age, any participation level. Intervention: Any injury prevention programme.	Sample: 12 studies, 11,773 cases. Main findings: Effectiveness of injury prevention: overall - Multicomponent programmes reduce overall injury incidence by 27%.

Table 2. Continued.

Author	NHMRC level of evidence	Study characteristics	Results
		Comparator: Standard activity.	Effectiveness of injury prevention: ACL injuries - Multicomponent programmes reduce overall ACL injuries by 45%.
		Outcome: Injury incidence, any injury.	Effectiveness of injury prevention: knee/ankle/hip/groin injuries - Multicomponent programmes reduce overall injury incidence in knee 15%–17%; ankle 17%–22%; hip/groin 25%–29%.
		Study design: Systematic review and meta-analysis.	Effectiveness of injury prevention: hamstring injuries - Hamstring injuries were reduced by 40%–60% with a significant proportion using the FIFA 11+. Single-component injury prevention programmes demonstrated 81%–84% reduction in injuries and were more effective than multiple component programmes.
Postoperative rehabilitation			
Figueroa et al, 2024	I	Sport: Any. Population: Female athletes post- ACLR. Intervention: ACLR in elite athletes. Comparator: ACLR in non-elite athletes. Outcome: Return to sport rates, time to return to sport, level of sport returned, and reasons for not returning. Study design: Systematic review and meta-analysis.	Sample: 15 studies, 1456 female athletes. Main findings: 69% of non-elite female athletes can return to sport at average of 10.8 months. 79% of elite female athletes return to sport. 87.7% of elite athletes return to pre-injury level.
Kotsifaki et al, 2023	I	Sport: Any. Population: Male and female patients ≥16 years old, post ACL surgery.	Sample: 140 randomised control trials. Main findings: Clinical practice guideline recommendations include:

Table 2. Continued.

Author	NHMRC level of evidence	Study characteristics	Results
		Intervention: Physical therapy intervention. Comparator: No intervention, a placebo or standard care. Study design: Systematic review.	Preoperative rehabilitation Individual-specific duration of the rehabilitation protocol Neuromuscular electrical stimulation early post-surgery Active knee motion immediately Controlled early weight-bearing (first week) Open kinetic chain exercise, limited range of motion from the 4th week after surgery Combination of eccentric and concentric training Motor control and strength training Exclusive use of isokinetic training not advised
Kasmi et al, 2021	II	Sport: Any. Population: Elite female athletes post ACL surgery, who had already completed a 12-week traditional postoperative rehabilitation programme. Surgery: All ACL reconstructions (Bone patella tendon bone graft) performed by 2 surgeons with 20+ years experience. Intervention: 3 groups: 6-week training programme including eccentric only, plyometric only or both eccentric and plyometric training, alongside traditional rehabilitation. Comparator: Traditional rehabilitation only. Outcome: Lysholm knee scale, return to sport, functional testing. Study design: Randomised control trial.	Sample: n = 40. Main findings: Combined eccentric and plyometric training demonstrated significantly greater improvements in dynamic balance, return to sport index, leg symmetry and Lysholm knee scale and functional testing.

ACL, anterior cruciate ligament; ACLR, ACL reconstruction; FIFA, Federation Internationale de Football Association; IP, incidence proportion; IR, incidence rate.

mechanisms of pivoting, for example (Herzberg et al, 2017). The follicular and ovulatory phases of the cycle may increase ACL vulnerability, while the luteal phase, associated with elevated relaxin levels, may further compound this (Mancino et al, 2024). However, a systematic review disputed this by reporting that the luteal phase appeared to be least associated with ACL injury, demonstrating the vast uncertainty of how hormones affect ligamentous injury (Herzberg et al, 2017). ACL's exposed to oestradiol in cell culture have been associated with less fibroblast proliferation and dysregulated collagen synthesis in a dose-dependent manner, suggesting there may be a direct effect on ligament cell structure (Yu et al, 1999). The role of fluctuating hormones increasing risk is further supported by evidence showing females aged 15–19 on the oral contraceptive pill experienced a 63% reduction in ACL injury risk. Additionally, an overall odds ratio of 0.82 for requiring ACLR was observed among women of all ages taking oral contraceptives (DeFroda et al, 2019). There is inhibition of follicular development and subsequent ovulation with hormonal contraceptives, a stage that is usually linked to higher ACL injury risks (Herzberg et al, 2017). Literature on ACL injury and menstrual hormones has surged over the last decade, but the overall strength of evidence is low. It has been suggested that future research should focus on long observational studies with large interventional trials of follicular suppression and ongoing hormonal assays (Herzberg et al, 2017). There is much debate on this topic; a systematic review and meta-analysis found that a high ACL injury risk was not overwhelmingly associated with laxity and therefore hormonal effects of the menstrual cycle may not be as relevant as hypothesized (Somerson et al, 2019). An additional neuromuscular variable contributing to female athlete knee injuries is the lower hamstring-to-quadriceps ratios and increased quadriceps angle (Q-angle) (Raj et al, 2023). This imbalance may lead to insufficient muscular control of the knee joint, increasing the risk of injury (Mancino et al, 2024).

Prevention Strategies for ACL Injury

Prevention programmes have focussed on addressing the biomechanical and neuromuscular risk factors, with promising results (Table 2). Neuromuscular training (NMT) programmes have been proposed, such as the Prevent Injury and Enhance Performance (Mandelbaum et al, 2005) and FIFA 11+ programmes (Impellizzeri et al, 2013). A multi-component programme of strength, mobility, agility, and balance activities may facilitate a 45% reduction in ACL injuries, as seen in a systematic review of female football players, albeit low-level evidence (Crossley et al, 2020). Notably, multimodal exercise regimes have been more effective compared to NMT with a single type of exercise (Crossley et al, 2020; Sugimoto et al, 2015). However, the number of studies evaluating NMT encompassing female football players is limited. A meta-analysis of NMT programmes demonstrated a relative risk reduction of 73.4% and 43.8% for non-contact and overall ACL injuries respectively among female athletes (Sugimoto et al, 2012b). NMT was found to be more effective when implemented at a younger age, with greater compliance, duration, and frequency. Feedback cues highlighted appropriate knee alignment and movement patterns (Sugimoto et al, 2012a; Myer et al, 2013). One such study

that identified a cohort of 11–13-year-old female netball players reported that a 6-week NMT programme may improve the biomechanical landings that are linked to ACL injury (Hopper et al, 2017). For elite athletes, the pre-season timeframe may be imperative for NMT implementation; a study evaluating the role of NMT versus endurance training in pre-season female soccer players found that injury burden and occurrence was significantly lower in athletes undergoing NMT, more than 65% and 50% respectively (Belamjahad et al, 2024).

The introduction of artificial intelligence (AI) is an ever-evolving domain with potential applications in injury prevention. A study involving the use of machine learning algorithms on 791 elite female handball and football players analysed its capability to predict an ACL injury in this at-risk population. Whilst theoretically beneficial, and with room for improvement given AI's infancy, this study showed an average area under the Receiver Operating Characteristic Curve (AUC-ROC) of just 0.63 and therefore cannot be reliably generalised (Munoz-Macho et al, 2024).

Prevention of re-injury after ACLR involves dedicated rehabilitation programmes, although there is little consensus on the timing, duration, and progression of the exercises, as well as optimal timing for RTS (Webster, 2021). Evidence ranging from moderate to high supports pre-habilitation prior to surgery and early rehabilitation post-surgery, showing improvements in pain, mobility, and strength compared to delayed initiation of rehabilitation exercises (Webster, 2021). However, the evidence remains sparse and of variable quality. Larger and more rigorous studies are warranted to establish the appropriate programmes to prevent re-injury, tailored to the athlete and graft type used.

Gender Specific Considerations in the Treatment of ACL Injuries

ACL injury is an extensively researched domain of sports medicine. Popular autograft options for ACLR include bone-patellar tendon-bone (BPTB), hamstring tendon, and quadricep tendon, as well as allograft options (Inclan and Brophy, 2023). Studies have shown that BPTB autografts may show superiority with lower re-rupture rates among females under 21 years compared to hamstring tendon autografts (Maletis et al, 2013; Maletis et al, 2015). Data from the Norwegian Cruciate Ligament Registry suggests that ACLR with hamstring autograft is associated with a 2.3 hazard ratio of re-injury compared to BPTB grafts, and up to 4 times when isolating females aged 15 to 19 years (Persson et al, 2014). To address the smaller diameter of hamstring autografts observed in female patients, enhancing the graft to over 8 milimetres may be advised (Conte et al, 2014)

The integration of lateral extra-articular tenodesis (LET) with ACL reconstruction offers an additional safeguard. LET significantly improves graft stability and reduces the risk of graft failure. This approach has been reported to reduce the odds of graft failure by up to 60% with a hamstring graft (Firth et al, 2022), and a study of LET use in elite female football players found that no participants sustained a re-injury or complication throughout a mean follow-up of 6 years (Guzzini et al, 2016).

RTS rates post-ACLR differ significantly between genders, with males generally achieving higher rates of RTS compared to females, where it can be as low as

22%. This disparity highlights the necessity for developing more refined, gender-specific RTS criteria to address the unique recovery needs of female athletes effectively (Figueroa et al, 2024).

Ankle Injuries

Ankle injuries, particularly acute and chronic ligament instability, are reported to occur more frequently in female athletes compared to male counterparts in sports such as volleyball, basketball, swimming, diving, and baseball (Gianakos et al, 2022; Talia et al, 2024; Wingo et al, 2023). It has been reported that ankle sprains are more common in elite female athletes within National Collegiate Athletics Association Division 1 institutions, compared to males of a similar athletic ability (Hunt et al, 2017). Despite this disparity, only 16.7% of studies in high-impact journals encapsulate gender as a variable in statistical models, despite Sex and Gender Equity in Research guidelines encouraging the reporting of these differences to enhance generalisability (Gianakos et al, 2020; Talia et al, 2024).

Risk Factors for Ankle Injuries

Talia et al (2024) conducted a systematic review on various risk factors of females suffering noticeably higher rates of foot and ankle injuries. Predispositions identified include ligament laxity, increased ankle range of motion and the use of footwear designed primarily for male anatomy. Additionally, higher oestrogen levels in women were reported to affect the fibroblastic response during soft tissue repair and lower overall ligament tensile strength (Caldemeyer et al, 2020; Talia et al, 2024). The link between the menstrual cycle and ankle is not well understood but one study did determine that there was significant posture sway and ankle muscle elasticity during the ovulatory phase of 16 young women. It was postulated that oestrogen increased ankle joint and surrounding muscle laxity, leading to suboptimal posture stability, and that this varied during the menstrual cycle (Yim et al, 2018). In contrast, a 2022 systematic review and meta-analysis by Mason et al (2022) reported that reduced concentric dorsiflexion strength in sportswomen predisposed to an ankle sprain but reported no other notable risk factors.

Prevention of Ankle Injuries

A systematic review by Caldemeyer et al (2020) evaluated female-specific data for NMT preventing ankle sprains. Through a combination of strength work, plyometrics, balance, and agility exercises, they found an overall trend of efficacious sprain prevention. Similarly, the FIFA 11+ programme, aimed at preventing injuries and reinjuries in female athletes, has been associated with lower injury rates, including ankle trauma, by up to 80% (Magoshi et al, 2023). However, despite these encouraging results, concerns have been raised regarding the FIFA 11+ programme on the prevention of ankle injuries. It had been reported to temporarily decrease agility and performance compared to dynamic warm-ups, thus increasing acute injury risk (Asgari et al, 2023). Additionally, poor uptake among coaches has been identified, with limited engagement and time spent on non-football skills (Asgari et al, 2023). 29 elite female futsal athletes were measured for explosive

strength and agility after 5 weeks of FIFA 11+, they found significant improvements in both strength and agility in the experimental group, whilst the control improved in agility but not explosive strength. This therefore disputes the worry that FIFA 11+ may adversely impact speed and agility (Patti et al, 2022). Overall, the lack of gender-specific research remains a recurring issue in sports medicine and definitive measures to mitigate injury risk are still awaited (Talia et al, 2024). Perhaps a hybrid regime of FIFA 11+ with personalised strategies, using a blend of AI to assess athlete risk for certain injuries, would be a more tailored approach to injury prevention.

Treatment of Ankle Injuries

The severity of the ankle sprains will ultimately dictate the treatment strategy, ranging from conservative measures such as rest and graded strengthening to surgical intervention. In a study exploring injury among elite female basketball players in the Women's National Basketball Association, 47.8% sustained an ankle sprain, with 2.6% requiring surgical reconstruction (McCarthy et al, 2013). If ankle ligament reconstruction is required, ligamentous laxity seen in female patients may put them at higher risk of postoperative failure; a study by Xu and Lee (2016) found a failure rate of 11.4% in the laxity group versus just 1.8% in the non-laxity group. Although, this research was carried out on both male and female participants (Xu and Lee, 2016). Post-injury rehabilitation emphasises early physiotherapy focusing on restoring full range of motion, resistance exercises, proprioceptive, and sport-specific training (Gianakos et al, 2022).

Hamstring Injuries

HSI represents one of the commonest injuries experienced by female athletes, (particularly in football and high intensity running sports) often resulting in prolonged rehabilitation and time out of play, with large financial, physical, and emotional implications (Table 1) (O'Sullivan et al, 2022). In women's elite-level football, HSI accounts for up to 16% of all time-loss injuries (Ekstrand et al, 2023; Hallén et al, 2024). These injuries can significantly impair function owing to scarring of adjacent neurological structures, leading to early career retirement (O'Sullivan et al, 2022). Research specific to males may not be directly applicable to females due to biomechanical differences, highlighting the importance of identifying gender-specific risk (O'Sullivan et al, 2022). A prospective European study into the Union of European Football Associations women's elite football players identified high intensity running as the leading mechanism of HSI, indicating the need for targeted preventative and rehabilitative strategies (Hallén et al, 2024). Ongoing trials aim to optimise these approaches, although recurrence remains a concern, with 1 in 6 injuries being a repeat occurrence (Hallén et al, 2024).

Risk Factors for Hamstring Injuries

Proposed risk factors for HSI include older age, previous HSI, increased flexibility, and greater skeletal muscle fatigue resistance compared to males (Table 1) (O'Sullivan et al, 2022). Anatomical differences, such as a larger acetabular an-

teversion (21–23 degrees in females compared to 17–18 degrees in males) and increased anterior pelvic tilt, forces the hamstrings into a lengthened position, potentially increasing susceptibility to HSI (O'Sullivan et al, 2022). Some research suggests a protective role of hormonal factors; in female athletes, oestrogen has been associated with decreased muscle stiffness (Bell et al, 2012) and post-menopausal women on hormone replacement therapy show increased muscle strength (Greising et al, 2009). However, the relationship between the menstrual cycle and HSI risk remains inconclusive (Miyazaki and Maeda, 2022).

Extrinsic factors, such as coaching styles, have also been implicated. Female professional footballers may experience increased injury risk due to excessive fatigue and match overload, coupled with training regimens that fail to replicate match conditions (Ekstrand et al, 2023). It has been suggested that a more constant 'match play' training environment may help condition athletes' hamstrings to withstand the demands of intense gameplay (Ekstrand et al, 2023).

Prevention of Hamstring Injuries

Evidence-based HSI prevention programmes specifically tailored to female athletes remain limited. Among these, the Nordic eccentric hamstring exercises have been reported to reduce HSI risk by up to 70% in some studies (Afonso et al, 2024; Buckthorpe et al, 2019). Rehabilitation exercises have yielded mixed results, while low-level laser therapy and platelet rich plasma injections have shown little effect in preventing re-injury and facilitating RTS (Afonso et al, 2023). Tailored prevention programmes that consider individual factors such as agility, speed, power, neuromuscular control, hamstring strength, psychological profile and injury history are recommended (Buckthorpe et al, 2019). A research team has proposed a five-point strategy for injury prevention in elite footballers, which includes hamstring strengthening; monitoring of players training and recovery; lumbopelvic hip stability improvement; improving physical conditioning; movement quality (Buckthorpe et al, 2019). Elite female athletes may soon utilise the power of artificial neural networks that predict muscle strain injuries. By processing athlete data, training regime, and other relevant variables, this would theoretically have capacity to continuously generate unique risk profiles and adapt prevention techniques (Musat et al, 2024).

Treatment of Hamstring Injuries

The management of HSI is often conservative, but more severe cases, such as grade 2 or 3 tendon avulsions, may require surgical intervention, especially for high sporting demand athletes (Plastow et al, 2022). Surgical treatment for high-grade proximal HSI has been reported to significantly enhance patient satisfaction and hamstring strength compared to non-operative approaches; however, some research shows comparable outcomes between the strategies (Bodendorfer et al, 2018; Buckwalter et al, 2017; van der Made et al, 2022). The objective of surgical intervention is to reapproximate the tendon, restoring its length and tension to improve muscle function. According to the 2020 London International Hamstring Consensus, indications for surgical repair include: significant gapping at the tendon in-

jury site, symptomatic and displaced bony avulsions, and proximal free tendon injuries that do not respond to non-surgical management. The decision-making for surgical intervention should consider the athlete's demands and the expected functional outcomes. This approach is essential as non-operative management might risk significant functional loss. Incorporating eccentric strengthening exercises into the rehabilitation process can accelerate recovery and help prevent future injuries (O'Sullivan et al, 2022).

Conclusion

There is a growing body of evidence on soft tissue injuries in elite female athletes amidst a challenging and demanding career pathway of contact and non-contact sports. The complex, multifaceted aetiology of soft tissue injury in female athletes cannot be solely explained by physiological and anatomical differences, and therefore, a more holistic bio-psycho-social take is required to adequately address risk factors, prevention, and management. There is a clear need for gender-specific and sport-specific training programmes to prevent injuries but also improve outcomes in the event of injury occurrence with more personalised rehabilitation, as the current system is still divided in clinical success between male and female athletes. This need is further validated by calls from elite sporting organisations to prioritise player welfare and acknowledge gender-specific physiological needs. Clinicians should be cognisant of the economic, physical, and psychological risk factors associated with increased injury in the female athlete to ensure robust preventative services are implemented. Equally important is the awareness of the social, cultural, and contextual barriers inherent in a field still predominantly shaped by male-focused research. Going forward, researchers should aim to validate and assess the effectiveness of preventative methods tailored to female athletes in larger cohort studies, as well as evaluate the significance of different risk factors that may put female athletes at higher likelihood of sustaining soft tissue injury.

Key Points

- Rising soft tissue injury rates in elite female athletes are multifaceted and complex with an interplay of bio-psycho-physiological factors, that must be acknowledged to minimise risk.
- The impact of the menstrual cycle and hormonal fluctuations in females are often linked with increased rates of ACL injury among elite female athletes, as well as ankle and hamstring trauma.
- Surgical and non-surgical treatment of soft tissue injury requires a tailored approach to female athletes, to sufficiently mitigate against the higher failure and recurrence rates seen.
- Research into female-specific prevention programmes for elite athletes is lacking and necessitates more consideration to adequately prevent and address the higher soft tissue injury rates.

Availability of Data and Materials

The authors confirm that the data supporting the findings of this study are available within the article.

Author Contributions

ASP — Conceptualization; Visualization; Methodology; Investigation; Data Curation; Writing - Original draft; Writing - Review & Editing. ABLK — Conceptualization; Visualization; Methodology; Investigation; Data Curation; Writing - Original draft; Writing - Review & Editing. MT — Conceptualization; Visualization; Methodology; Investigation; Data Curation; Writing - Original draft; Writing - Review & Editing. AF — Conceptualization; Visualization; Methodology; Data Curation; Writing - Review & Editing; Supervision. FSH — Conceptualization; Methodology; Writing - Review & Editing; Supervision. All authors gave final approval of the version to be published. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgement

Fig. 1 was produced by Canva. The authors confirm that every aspect of this manuscript has been rigorously reviewed and refined, and they take complete responsibility for its accuracy, integrity, and originality.

Funding

This research received no external funding.

Conflict of Interest

Fares S Haddad reports board membership of the Bone & Joint Journal and the Annals of the Royal College of Surgeons of England; consultancy for Smith & Nephew, Corin, MatOrtho, and Stryker, payment for lectures, including service on speakers' bureaus, for Smith & Nephew and Stryker; and royalties paid by Smith & Nephew, MatOrtho, Corin, and Stryker. Andreas Fontalis reports institutional research support from Stryker. All authors declare no conflict of interest related to this work.

References

Afonso J, Olivares-Jabalera J, Fernandes RJ, Clemente FM, Rocha-Rodrigues S, Claudino JG, et al. Effectiveness of Conservative Interventions After Acute Hamstrings Injuries in Athletes: A Living Systematic Review. Sports Medicine. 2023; 53: 615–635. https://doi.org/10.1007/s40279-022-01783-z

Afonso J, Reurink G, Clemente FM, Ramirez-Campillo R, Pizzari T, Andrade R. Revisiting the hamstring injury prevention and rehabilitation literature: filling the gaps! British Journal of Sports Medicine. 2024; 58: 243–244. https://doi.org/10.1136/bjsports-2023-106878

Al Attar WSA, Bakhsh JM, Khaledi EH, Ghulam H, Sanders RH. Injury prevention programs that include plyometric exercises reduce the incidence of anterior cruciate ligament injury: a systematic review of cluster randomised trials. Journal of Physiotherapy. 2022; 68: 255–261. https://doi.org/10.1016/j.jphys.2022.09.001

Asgari M, Nazari B, Bizzini M, Jaitner T. Effects of the FIFA 11+ program on performance, biomechanical measures, and physiological responses: A systematic review. Journal of Sport and Health Science. 2023; 12: 226–235. https://doi.org/10.1016/j.jshs.2022.05.001

Basu S, Goswami AG, David LE, Mudge E. Psychological Stress on Wound Healing: A Silent Player in a Complex Background. The International Journal of Lower Extremity Wounds. 2022; 23: 365–371. https://doi.org/10.1177/15347346221077571

Belamjahad A, Tourny C, Jebabli N, Clark CCT, Laher I, Hackney AC, et al. Effects of a Preseason Neuromuscular Training Program vs. an Endurance-Dominated Program on Physical Fitness and Injury Prevention in Female Soccer Players. Sports Medicine - Open. 2024; 10: 76. https://doi.org/10.1186/s40798-024-00731-7

Bell DR, Blackburn JT, Norcross MF, Ondrak KS, Hudson JD, Hackney AC, et al. Estrogen and muscle stiffness have a negative relationship in females. Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA. 2012; 20: 361–367. https://doi.org/10.1007/s00167-011-1577-y

Bodendorfer BM, Curley AJ, Kotler JA, Ryan JM, Jejurikar NS, Kumar A, et al. Outcomes After Operative and Nonoperative Treatment of Proximal Hamstring Avulsions: A Systematic Review and Meta-analysis. The American Journal of Sports Medicine. 2018; 46: 2798–2808. https://doi.org/10.1177/0363546517732526

Brewer BW, Van Raalte JL, Cornelius AE. An Interactive Cognitive-Behavioural Multimedia Program Favourably Affects Pain and Kinesiophobia During Rehabilitation After Anterior Cruciate Ligament Surgery: An Effectiveness Trial. International Journal of Sport and Exercise Psychology. 2022; 20: 1133–1155. https://doi.org/10.1080/1612197x.2021.1934712

Bruder AM, Culvenor AG, King MG, Haberfield M, Roughead EA, Mastwyk J, et al. Let's talk about sex (and gender) after ACL injury: a systematic review and meta-analysis of self-reported activity and knee-related outcomes. British Journal of Sports Medicine. 2023; 57: 602–610. https://doi.org/10.1136/bjsports-2022-106099

Buckthorpe M, Wright S, Bruce-Low S, Nanni G, Sturdy T, Gross AS, et al. Recommendations for hamstring injury prevention in elite football: translating research into practice. British Journal of Sports Medicine. 2019; 53: 449–456. https://doi.org/10.1136/bjsports-2018-099616

Buckwalter J, Westermann R, Amendola A. Complete proximal hamstring avulsions: is there a role for conservative management? A systematic review of acute repairs and non-operative management. Journal of ISAKOS. 2017; 2: 31–35. https://doi.org/10.1136/JISAKOS-2016-000105

Caldemeyer LE, Brown SM, Mulcahey MK. Neuromuscular training for the prevention of ankle sprains in female athletes: a systematic review. The Physician and Sportsmedicine. 2020; 48: 363–369. https://doi.org/10.1080/00913847.2020.1732246

Conte EJ, Hyatt AE, Gatt CJ Jr, Dhawan A. Hamstring autograft size can be predicted and is a potential risk factor for anterior cruciate ligament reconstruction failure. Arthroscopy: the Journal of Arthroscopic & Related Surgery: Official Publication of the Arthroscopy Association of North America and the International Arthroscopy Association. 2014; 30: 882–890. https://doi.org/10.1016/j.arthro.2014.03.028

Coronado RA, Sterling EK, Fenster DE, Bird ML, Heritage AJ, Woosley VL, et al. Cognitive-behavioral-based physical therapy to enhance return to sport after anterior cruciate ligament reconstruction: An open pilot study. Physical Therapy in Sport: Official Journal of the Association of Chartered Physiotherapists in Sports Medicine. 2020; 42: 82–90. https://doi.org/10.1016/j.ptsp.2020.01.004

Crossley KM, Patterson BE, Culvenor AG, Bruder AM, Mosler AB, Mentiplay BF. Making football safer for women: a systematic review and meta-analysis of injury prevention programmes in 11 773 female football (soccer) players. British Journal of Sports Medicine. 2020; 54: 1089–1098. https://doi.org/10.1136/bjsports-2019-101587

Dane K, Foley G, Cullen P, Wilson F. "Women shouldn't play rugby" – the gendered and embodied experiences of women players in rugby union. Qualitative Research in Sport, Exercise and Health. 2024; 16: 487–502. https://doi.org/10.1080/2159676X.2024.2375395

DeFroda SF, Bokshan SL, Worobey S, Ready L, Daniels AH, Owens BD. Oral contraceptives provide protection against anterior cruciate ligament tears: a national database study of 165,748 female patients. The Physician and Sportsmedicine. 2019; 47: 416–420. https://doi.org/10.1080/00913847.2019.1600334

Edama M, Inaba H, Hoshino F, Natsui S, Maruyama S, Omori G. The relationship between the female athlete triad and injury rates in collegiate female athletes. PeerJ. 2021; 9: e11092. https://doi.org/10.7717/peerj.11092

Ekstrand J, Hallén A, Marin V, Gauffin H. Most modifiable risk factors for hamstring muscle injury in women's elite football are extrinsic and associated with the club, the team, and the coaching staff and not the players themselves: the UEFA Women's Elite Club Injury Study. Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA. 2023; 31: 2550–2555. https://doi.org/10.1007/s00167-023-07429-5

Figueroa D, Figueroa ML, Figueroa F. Return to sports in female athletes after anterior cruciate ligament reconstruction: A systematic review and metanalysis. Journal of ISAKOS: Joint Disorders & Orthopaedic Sports Medicine. 2024; 9: 378–385. https://doi.org/10.1016/j.jisako.2024.01.008

Firth AD, Bryant DM, Litchfield R, McCormack RG, Heard M, MacDonald PB, et al. Predictors of Graft Failure in Young Active Patients Undergoing Hamstring Autograft Anterior Cruciate Ligament Reconstruction With or Without a Lateral Extra-articular Tenodesis: The Stability Experience. The American Journal of Sports Medicine. 2022; 50: 384–395. https://doi.org/10.1177/03635465211061150

Fox A, Bonacci J, Hoffmann S, Nimphius S, Saunders N. Anterior cruciate ligament injuries in Australian football: should women and girls be playing? You're asking the wrong question. BMJ Open Sport & Exercise Medicine. 2020; 6: e000778. https://doi.org/10.1136/bmjsem-2020-000778

Gianakos AL, Abdelmoneim A, Kerkhoffs G, Mulcahey MK. Rehabilitation and Return to Sport of Female Athletes. Arthroscopy, Sports Medicine, and Rehabilitation. 2022; 4: e247–e253. https://doi.org/10.1016/j.asmr.2021.09.040

Gianakos AL, George N, Merklein M, Chambers L, Ferkel R, DiGiovanni C, et al. Foot and Ankle Related Sex-Specific Analysis Within High-Impact Journals. Foot & Ankle International. 2020; 41: 356–363. https://doi.org/10.1177/1071100719894530

Greising SM, Baltgalvis KA, Lowe DA, Warren GL. Hormone therapy and skeletal muscle strength: a meta-analysis. The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences. 2009; 64: 1071–1081. https://doi.org/10.1093/gerona/glp082

Guzzini M, Mazza D, Fabbri M, Lanzetti R, Redler A, Iorio C, et al. Extra-articular tenodesis combined with an anterior cruciate ligament reconstruction in acute anterior cruciate ligament tear in elite female football players. International Orthopaedics. 2016; 40: 2091–2096. https://doi.org/10.1007/s00264-016-3261-9

Hallén A, Tomás R, Ekstrand J, Bengtsson H, Van den Steen E, Hägglund M, et al. UEFA Women's Elite Club Injury Study: a prospective study on 1527 injuries over four consecutive seasons 2018/2019 to 2021/2022 reveals thigh muscle injuries to be most common and ACL injuries most burdensome. British Journal of Sports Medicine. 2024; 58: 128–135. https://doi.org/10.1136/bjsports-2023-107133

Hardaker NJ, Hume PA, Sims ST. Differences in Injury Profiles Between Female and Male Athletes Across the Participant Classification Framework: A Systematic Review and Meta-Analysis. Sports Medicine. 2024; 54: 1595–1665. https://doi.org/10.1007/s40279-024-02010-7

Herzberg SD, Motu'apuaka ML, Lambert W, Fu R, Brady J, Guise JM. The Effect of Menstrual Cycle and Contraceptives on ACL Injuries and Laxity: A Systematic Review and Meta-analysis. Orthopaedic Journal of Sports Medicine. 2017; 5: 2325967117718781. https://doi.org/10.1177/2325967117718781

Hopper AJ, Haff EE, Joyce C, Lloyd RS, Haff GG. Neuromuscular Training Improves Lower Extremity Biomechanics Associated with Knee Injury during Landing in 11–13 Year Old Female Netball Athletes: A Randomized Control Study. Frontiers in Physiology. 2017; 8: 883. https://doi.org/10.3389/fphys.2017.00883

Hunt KJ, Hurwit D, Robell K, Gatewood C, Botser IB, Matheson G. Incidence and Epidemiology of Foot and Ankle Injuries in Elite Collegiate Athletes. The American Journal of Sports Medicine. 2017; 45: 426–433. https://doi.org/10.1177/0363546516666815

Impellizzeri FM, Bizzini M, Dvorak J, Pellegrini B, Schena F, Junge A. Physiological and performance responses to the FIFA 11+ (part 2): a randomised controlled trial on the training effects. Journal of Sports Sciences. 2013; 31: 1491–1502. https://doi.org/10.1080/02640414.2013.802926

Inclan PM, Brophy RH. Revision anterior cruciate ligament reconstruction. The Bone & Joint Journal. 2023; 105-B: 474–480. https://doi.org/10.1302/0301-620X.105B5.BJJ-2022-1064.R1

Kasmi S, Zouhal H, Hammami R, Clark CCT, Hackney AC, Hammami A, et al. The Effects of Eccentric and Plyometric Training Programs and Their Combination on Stability and the Functional Performance in the Post-ACL-Surgical Rehabilitation Period of Elite Female Athletes. Frontiers in Physiology. 2021; 12: 688385. https://doi.org/10.3389/fphys.2021.688385

Kotsifaki R, Korakakis V, King E, Barbosa O, Maree D, Pantouveris M, et al. Aspetar clinical practice guideline on rehabilitation after anterior cruciate ligament reconstruction. British Journal of Sports Medicine. 2023; 57: 500–514. https://doi.org/10.1136/bjsports-2022-106158

Macdonald B, McAleer S, Kelly S, Chakraverty R, Johnston M, Pollock N. Hamstring rehabilitation in elite track and field athletes: applying the British Athletics Muscle Injury Classification in clinical practice. British Journal of Sports Medicine. 2019; 53: 1464–1473. https://doi.org/10.1136/bjsports-2017-098971

Magoshi H, Hoshiba T, Tohyama M, Hirose N, Fukubayashi T. Effect of the FIFA 11+ injury prevention program in collegiate female football players over three consecutive seasons. Scandinavian Journal of Medicine & Science in Sports. 2023; 33: 1494–1508. https://doi.org/10.1111/sms.14379

Mahajan PS, Chandra P, Negi VC, Jayaram AP, Hussein SA. Smaller anterior cruciate ligament diameter is a predictor of subjects prone to ligament injuries: an ultrasound study. BioMed Research International. 2015; 2015: 845689. https://doi.org/10.1155/2015/845689

Maletis GB, Inacio MCS, Desmond JL, Funahashi TT. Reconstruction of the anterior cruciate ligament: association of graft choice with increased risk of early revision. The Bone & Joint Journal. 2013; 95-B: 623–628. https://doi.org/10.1302/0301-620X.95B5.30872

Maletis GB, Inacio MCS, Funahashi TT. Risk factors associated with revision and contralateral anterior cruciate ligament reconstructions in the Kaiser Permanente ACLR registry. The American Journal of Sports Medicine. 2015; 43: 641–647. https://doi.org/10.1177/0363546514561745

Mancino F, Kayani B, Gabr A, Fontalis A, Plastow R, Haddad FS. Anterior cruciate ligament injuries in female athletes: risk factors and strategies for prevention. Bone & Joint Open. 2024; 5: 94–100. https://doi.org/10.1302/2633-1462.52.BJO-2023-0166

Mandelbaum BR, Silvers HJ, Watanabe DS, Knarr JF, Thomas SD, Griffin LY, et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. The American Journal of Sports Medicine. 2005; 33: 1003–1010. https://doi.org/10.1177/0363546504272261

Mason J, Kniewasser C, Hollander K, Zech A. Intrinsic Risk Factors for Ankle Sprain Differ Between Male and Female Athletes: A Systematic Review and Meta-Analysis. Sports Medicine - Open. 2022; 8: 139. https://doi.org/10.1186/s40798-022-00530-y

McCarthy MM, Voos JE, Nguyen JT, Callahan L, Hannafin JA. Injury profile in elite female basketball athletes at the Women's National Basketball Association combine. The American Journal of Sports Medicine. 2013; 41: 645–651. https://doi.org/10.1177/0363546512474223

Miyazaki M, Maeda S. Changes in hamstring flexibility and muscle strength during the menstrual cycle in healthy young females. Journal of Physical Therapy Science. 2022; 34: 92–98. https://doi.org/10.1589/jpts.34.92

Montalvo AM, Schneider DK, Yut L, Webster KE, Beynnon B, Kocher MS, et al. "What's my risk of sustaining an ACL injury while playing sports?" A systematic review with meta-analysis. British Journal of Sports Medicine. 2019; 53: 1003–1012. https://doi.org/10.1136/bjsports-2016-096274

Mullins K, Mac Colgáin D, Carton P. Incidence and Severity of Hamstring Injuries in Female Athletes Who Play Field Sports: A Systematic Review With Meta-Analysis of Prospective Studies. The Journal of Orthopaedic and Sports Physical Therapy. 2022; 52: 740–A5. https://doi.org/10.2519/jospt.2022.11144

Munoz-Macho AA, Domínguez-Morales MJ, Sevillano-Ramos JL. Performance and healthcare analysis in elite sports teams using artificial intelligence: a scoping review. Frontiers in Sports and Active Living. 2024; 6: 1383723. https://doi.org/10.3389/fspor.2024.1383723

Musat CL, Mereuta C, Nechita A, Tutunaru D, Voipan AE, Voipan D, et al. Diagnostic Applications of AI in Sports: A Comprehensive Review of Injury Risk Prediction Methods. Diagnostics (Basel, Switzerland). 2024; 14: 2516. https://doi.org/10.3390/diagnostics14222516

Myer GD, Sugimoto D, Thomas S, Hewett TE. The influence of age on the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes: a meta-analysis. The American Journal of Sports Medicine. 2013; 41: 203–215. https://doi.org/10.1177/0363546512460637

Myrick KM, Voss A, Feinn RS, Martin T, Mele BM, Garbalosa JC. Effects of season long participation on ACL volume in female intercollegiate soccer athletes. Journal of Experimental Orthopaedics. 2019; 6: 12. https://doi.org/10.1186/s40634-019-0182-8

O'Sullivan L, Preszler J, Tanaka M. Hamstring Injury Rehabilitation and Prevention in the Female Athlete. International Journal of Sports Physical Therapy. 2022; 17: 1184–1193. https://doi.org/10.26603/001c.38254

Patti A, Giustino V, Cataldi S, Stoppa V, Ferrando F, Marvulli R, et al. Effects of 5-Week of FIFA 11+ Warm-Up Program on Explosive Strength, Speed, and Perception of Physical Exertion in Elite Female Futsal Athletes. Sports (Basel, Switzerland). 2022; 10: 100. https://doi.org/10.3390/sports10070100

Paul RW, Sonnier JH, Johnson EE, Hall AT, Osman A, Connors GM, et al. Inequalities in the Evaluation of Male Versus Female Athletes in Sports Medicine Research: A Systematic Review. The American Journal of Sports Medicine. 2023; 51: 3335–3342. https://doi.org/10.1177/03635465221131281

Persson A, Fjeldsgaard K, Gjertsen JE, Kjellsen AB, Engebretsen L, Hole RM, et al. Increased risk of revision with hamstring tendon grafts compared with patellar tendon grafts after anterior cruciate ligament reconstruction: a study of 12,643 patients from the Norwegian Cruciate Ligament Registry, 2004-2012. The American Journal of Sports Medicine. 2014; 42: 285–291. https://doi.org/10.1177/0363546513511419

Plastow R, Kayani B, Paton B, Moriarty P, Wilson M, Court N, et al. LONDON INTERNATIONAL CONSENSUS ON HAMSTRING INJURIES. Orthopaedic Proceedings. 2022; 104-B(SUPP_4): 38–38. https://doi.org/10.1302/1358-992X.2022.4.038

Pollock N, Kelly S, Lee J, Stone B, Giakoumis M, Polglass G, et al. A 4-year study of hamstring injury outcomes in elite track and field using the British Athletics rehabilitation approach. British Journal of Sports Medicine. 2022; 56: 257–263. https://doi.org/10.1136/bjsports-2020-103791

Prosak OL, Hajdu KS, Amedy A, Anesi TJ, Williams K, Jo J, et al. Sex Differences in Resource Allocation and Access to Care After Sport-Related Concussion. Journal of Athletic Training. 2024; 59: 785–792. https://doi.org/10.4085/1062-6050-0280.23

Raj RD, Fontalis A, Grandhi TSP, Kim WJ, Gabr A, Haddad FS. The impact of the menstrual cycle on orthopaedic sports injuries in female athletes. The Bone & Joint Journal. 2023; 105-B: 723–728. https://doi.org/10.1302/0301-620X.105B7.BJJ-2022-1262.R2

Ramos Pastrana L M, Giménez Egido J M, Olmedilla Zafra A. Psychological aspects associated with ACL rehabilitation and recurrence in football players: a systematic review. Retos. 2024; 55: 397–410. https://doi.org/10.47197/retos.v55.105115

Rowe D, Silva KKP. Women's sport and media: a call to critical arms. Feminist Media Studies. 2023; 23: 729–733. https://doi.org/10.1080/14680777.2023.2201663

Ruiz-Rios M, Setuain I, Cadore EL, Izquierdo M, Garcia-Tabar I. Physical Conditioning and Functional Injury-Screening Profile of Elite Female Soccer Players: A Systematic Review. International Journal of Sports Physiology and Performance. 2024; 19: 1355–1366. https://doi.org/10.1123/ijspp.2023-0463

Saltzman EB, Levin JM, Dagher AMB, Messer M, Kimball R, Lohnes J, et al. Injury prevention strategies at the 2019 FIFA Women's World Cup display a multifactorial approach and highlight subjective wellness measurements. Journal of ISAKOS: Joint Disorders & Orthopaedic Sports Medicine. 2023; 8: 325–331. https://doi.org/10.1016/j.jisako.2023.04.007

Siegel MG. Editorial Commentary: Women Do Not Return to Sport at the Same Level After Anterior Cruciate Ligament Reconstruction as Often as Men: This May Be Associated With Lower Risk Tolerance-and Not Necessarily a Bad Thing! Arthroscopy. 2024; 40: 1879–1881. https://doi.org/10.1016/j.arthro.2023.12.020

Somerson JS, Isby IJ, Hagen MS, Kweon CY, Gee AO. The Menstrual Cycle May Affect Anterior Knee Laxity and the Rate of Anterior Cruciate Ligament Rupture: A Systematic Review and Meta-Analysis.

JBJS Reviews. 2019; 7: e2. https://doi.org/10.2106/JBJS.RVW.18.00198

Sugimoto D, Myer GD, Bush HM, Klugman MF, Medina McKeon JM, Hewett TE. Compliance with neuromuscular training and anterior cruciate ligament injury risk reduction in female athletes: a meta-analysis. Journal of Athletic Training. 2012a; 47: 714–723. https://doi.org/10.4085/1062-6050-47.6.10

Sugimoto D, Myer GD, Foss KDB, Hewett TE. Specific exercise effects of preventive neuromuscular training intervention on anterior cruciate ligament injury risk reduction in young females: meta-analysis and subgroup analysis. British Journal of Sports Medicine. 2015; 49: 282–289. https://doi.org/10.1136/bjsports-2014-093461

Sugimoto D, Myer GD, McKeon JM, Hewett TE. Evaluation of the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes: a critical review of relative risk reduction and numbers-needed-to-treat analyses. British Journal of Sports Medicine. 2012b; 46: 979–988. https://doi.org/10.1136/bjsports-2011-090895

Talia AJ, Busuttil NA, Kendal AR, Brown R. Gender differences in foot and ankle sporting injuries: A systematic literature review. Foot. 2024; 60: 102122. https://doi.org/10.1016/j.foot.2024.102122

van der Made AD, Peters RW, Verheul C, Smithuis FF, Reurink G, Moen MH, et al. Proximal hamstring tendon avulsions: comparable clinical outcomes of operative and non-operative treatment at 1-year follow-up using a shared decision-making model. British Journal of Sports Medicine. 2022; 56: 340–348. https://doi.org/10.1136/bjsports-2021-104588

Webster KE. Return to Sport and Reinjury Rates in Elite Female Athletes After Anterior Cruciate Ligament Rupture. Sports Medicine. 2021; 51: 653–660. https://doi.org/10.1007/s40279-020-01404-7

Wicker P, Breuer C, Dallmeyer S. The gender earnings gap among elite athletes in semi-professional sports. Managing Sport and Leisure. 2023; 28: 583–600. https://doi.org/10.1080/23750472.2021.1944819

Wingo T, Gianakos AL, Mulcahey MK. Ankle Injuries in Female Athletes. Operative Techniques in Sports Medicine. 2023; 31: 151023. https://doi.org/10.1016/J.OTSM.2023.151023

Xu HX, Lee KB. Modified Broström Procedure for Chronic Lateral Ankle Instability in Patients With Generalized Joint Laxity. The American Journal of Sports Medicine. 2016; 44: 3152–3157. https://doi.org/10.1177/0363546516657816

Yim J, Petrofsky J, Lee H. Correlation between Mechanical Properties of the Ankle Muscles and Postural Sway during the Menstrual Cycle. The Tohoku Journal of Experimental Medicine. 2018; 244: 201–207. https://doi.org/10.1620/tjem.244.201

Yu WD, Liu SH, Hatch JD, Panossian V, Finerman GA. Effect of estrogen on cellular metabolism of the human anterior cruciate ligament. Clinical Orthopaedics and Related Research. 1999; 229–238. https://doi.org/10.1097/00003086-199909000-00030

Zouita A, Darragi M, Bousselmi M, Sghaeir Z, Clark CCT, Hackney AC, et al. The Effects of Resistance Training on Muscular Fitness, Muscle Morphology, and Body Composition in Elite Female Athletes: A Systematic Review. Sports Medicine. 2023; 53: 1709–1735. https://doi.org/10.1007/s40279-023-01859-4