Injuries in Female Soccer Players Pre- Versus In-Season: Does this differ between senior and academy players?

Linda Fettus

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Abstract

The aim of this injury audit was to investigate the characteristics of injuries during pre- and in-season in women's professional clubs and academies in England and Spain over two seasons.

Methods

This prospective study included 305 female soccer players (12-43 years old) recruited from four soccer clubs/academies in England and Spain in the 2021-22 and 2022-23 seasons. The soccer clubs' medical and sport science teams diagnosed injuries, while training and match hours were recorded via Global Positioning System or coaches' records. Players were categorised into four squad groups according to their age/playing level: (i) Under 14s (U14s); (ii) U16s; (iii) U21s; and (iv) senior squads. Injury incidence rate (IIR, i.e. injuries per 1000h) and burden (i.e. IIR × days lost) were calculated for overall U14s and U16s squads and the U21s and SNR squads were compared between pre- and in-season, and between squad groups. Severity was reported number of days lost.

Results

Overall, 308 injuries were recorded from 419 player seasons. For the senior players, muscular IIR was higher during pre-season (2.17 [95% CI: 1.38-3.41] injuries/1000h) vs. in-season (1.06 [95% CI: 0.75-1.51] injuries/1000h; $p<0.05$). Similarly, thigh IIR was higher during pre-season (1.24 [95% CI: 0.67-2.28] injuries/1000h) vs. in-season (0.45 [95% CI: 0.26-0.77] injuries/1000h; $p<0.05$). Regarding the U21 players, ligament/tendon IIR was higher in pre-season (4.06 [95% CI: 1.15–14.39] injuries/1000h) vs. in-season (0.96 [95% CI: 0.43–2.14] injuries/1000h; $p<0.05$). A similar pattern was seen regarding knee IIR in pre-season (4.06 [95% CI: 1.02–16.24 injuries/1000h) vs. in-season (0.64 [95% CI: 0.24–1.71] injuries/1000h). Concerning the between age-group analyses, both IIR and burden tended to increase with advancing age for most injury types/locations but then decreased in the senior players. The

quadriceps was most frequently injured muscle pre-season (66.7%), while the triceps surae was the most frequent muscular injury in-season (25.3%). Muscular injuries were most frequent in pre-season for the senior squads while ligament sprains were most frequent for the U21s, with the highest burden. During in-season, muscular and ligament injuries were most frequent across all squads with ligaments most burdensome.

Conclusion

Muscle and thigh IIR were higher in pre-season than in-season for the senior players, while knee and ligament/tendon IIR was higher in pre-season than in-season for the U21 players. Injury burden appeared to increase with advancing age but was lower in the senior squads compared to U21 and U16. This study highlights the need for demographic-specific strategies regarding injury prevention in pre-season vs. in-season, as well as according to age group.

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Declaration

I declare that the work contained within this thesis is entirely composed through work conducted by myself and directed by my supervisors. This has not been submitted in whole, or as a subsection, or part in any other works. Except for the inclusion of, and acknowledgement to evidence-based information which is clearly referenced.

The project received funding from the European Commission as part of the Erasmus+ Small Collaborative Partnerships scheme: the name of the project: ‘Female Soccer Players Regarding Genetics, Menstrual Cycle and Injury risk’, abbreviated to FEGEMI.

List of Abbreviations

FEGEMI - Female soccer players regarding Genetics, Menstrual Cycle and Injury risk

IIR – Injury Incidence Rate

IR – Injury Rate

IRR - Incidence Rate Ratio

IPP – Injury Prevalence Proportion

Overuse Injury – an injury that has a gradual onset and no known trauma has occurred

PHV – Peak Height Velocity

TLI – Time-Loss Injury

MC – Menstrual Cycle

PHV -Peak Height Velocity

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Chapter 1

Aims and Objectives

The broad aim of this thesis is to:

Investigate injuries within pre- and in-season in female soccer players.

This aim has been achieved through a narrative review of the available literature and the completion of an injury audit of two pre- and in-season time periods of senior and academy female soccer players.

The objectives of the narrative review are:

1. To provide the landscape of pre- versus in-season injury literature for female soccer players.
2. To explore injury epidemiology within female soccer players.
3. To acknowledge that female soccer players have different physiology profiles which may influence injury.

The objectives of the injury audit study are to identify if differences exist between pre- and in-season injury profiles including comparisons between senior and academy player injury profiles. Outcomes included:

1. Location, type, activity and tissue-type injured
2. Injury Incidence Rate (IIR)
3. Injury Burden
4. Comparison of youth (academy) player injuries versus senior player injuries.

Chapter 2

Narrative Review

A Narrative Review for Pre-Season Versus In-Season Injuries in Female Soccer Players: Acknowledging Physiological Influences

Abstract

Female participation in soccer has grown exponentially, which has led to a demand for female injury research. Current literature focuses primarily upon in-season injury epidemiology, leaving practitioners with a gap in the evidence base for pre-season injuries. Importantly, pre-season is to prepare athletes for the competitive phase, where a contrast exists between training approaches of season phases. Male-focused studies demonstrated injury incidence rate reduced when players participated in more pre-season sessions with a favourable decrease in injury burden. The aim of this review was to critically appraise the available literature in pre- and in-season injuries, with a particular focus on female soccer athletes. General injury reports demonstrate most injuries occurring to the lower limb and joint injuries resulting in the greatest burden. Female soccer athletes have a 21% higher number of days absence compared to males most likely due to more severe knee and ankle injuries versus male soccer athletes. Injury patterns differ between males and females within competitive seasons therefore pre- and in-season remain to be explored to gain clarity for types, locations, incidence and burden.

Introduction

The soccer landscape for women has evolved rapidly in recent years (Beech et al., 2024; Hallén et al., 2024). The increase in participation and professionalism have concurrently improved the resources available and, in turn, the performance of female soccer players at all levels of the game (Emmonds, Heyward and Jones, 2019a). However, the underrepresentation of female

participants in sports research has been widely reported (Emmonds, Heyward and Jones, 2019b; Smith et al., 2022; Paul et al., 2023)The increase in participation and professionalism have concurrently improved the resources available and, in turn, the performance of female soccer players at all levels of the game (Emmonds, Heyward and Jones, 2019a). However, the underrepresentation of female participants in sports research has been widely reported . Female-specific injury profiles, such as those considering different phases of the soccer season, have not received the same level of attention as their male-specific counterparts (Gilhooly et al., 2023). This lack of evidence to inform practitioners of prevalent injury patterns across different phases of the season in female soccer may negatively impact injury prevention strategies (Okholm Kryger et al., 2022).

Periodisation is a systematic approach described as the segmentation of a whole season into pre-season, in-season, post-season, and off-season periods (Matveev, 1981). This segmentation allows for the planning of macrocycles (entire season planning), mesocycles (usually several weeks), and microcycles (typically one week) to optimize focused performance enhancement goals for these specific periods within the season (Issurin, 2010). The pre-season typically follows an off-season that has no formal team training and/or matches. The pre-season aims to physically and mentally prepare athletes for the competitive nature of soccer, addressing intermittent aerobic and anaerobic requirements within a high-risk environment for injuries (Silva *et al.*, 2016). In Europe, pre-season begins in July for a duration of six-to-eight weeks, with an in-season duration estimated for 33 weeks (Costa, *et al.*, 2022) (including a winter break) with teams at different levels having variable durations (range of 25-33 weeks) (Belamjahad *et al.*, 2024). In-season is the competitive period when athletes compete against each other in domestic league, cup, or international competitions. These athletes have club organisational structures with appointed staff who work collaboratively to support athletes throughout the season. The athletes are required to have the skill, experience, and physical

qualities to fulfil the demands of the management team in their roles during matches to succeed and win matches. Other personnel, such as the medical and conditioning coaches have a variety of duties, some of which include instilling injury prevention, training/ rehabilitation measures and educational workshops to ensure player fitness, wellness and performance to support managers' and athletes' goals in succeeding and winning (age-dependent regarding developmental phases). However, recently it has been highlighted that sport science support staff responsible for the physical performance of female soccer players tend to be less qualified and experienced than those staff supporting male players (McQuilliam *et al.*, 2022). This is important to consider as it may impact the injury prevention strategies implemented throughout the pre/-in-season.

In recent years, women's soccer studies have demonstrated that the game is faster, with more aggressive playing styles in the modern game within elite youth (Emmonds *et al.*, 2017) and adult females (Bradley and Scott, 2020) compared to previous years (Lahti et al., 2020). Medical and coaching staff strive to reduce injuries experienced in-season by using pre-season to develop physical capacities to tolerate the loads experienced during the season. For example, Belamjahad *et al.* (2024) demonstrated that neuromuscular training strategies reduce the number of injuries compared to endurance training within female soccer players.

High injury rates and burden can lead to broader consequences, such as poor team performance (Coppalle *et al.*, 2019), persistent injury issues and financial consequences (Pulici *et al.*, 2023), many of which could be mitigated through a well-structured overall season plan. Injury severity is a vitally important issue that encompasses the extent of injury and recovery management (surgical or conservative management) ultimately affecting time to return to sport and performance (Gurau et al., 2023). Transparent research that addresses injury severity time for return to sport and performance assists clinicians in communicating with the player and wider performance support, and managerial teams regarding shared-decision making, risk

management and time-scales for player availability (Bahr et al., 2020a). This not only impacts planning and preparation for training sessions and matches but allows for realistic goal-setting for the rehabilitation process (Scobbie, Dixon and Wyke, 2010). Furthermore, highlighting injury burden demonstrates the impact of rare but devastating injuries (like the anterior cruciate ligament injury (López-Valenciano et al., 2019), high-severity injuries are not overlooked due to the reporting of frequent, less severe injuries hereby leading prevention programmes to target both frequent and severe injuries without misleading efforts in only reporting injury incidence (Waldén, Hägglund and Ekstrand, 2006). Based on the existing evidence, there are valuable insights to be further explored for pre-season benefits to reduce in-season injury incidence and burden. Strategies that can mitigate the injuries that occur within the female cohort may be implemented in pre-season and be effective in reducing injuries during in-season. This narrative review aims to investigate pre- and in-season injury characteristics with subsections describing key physiological characteristics within the female soccer athlete.

2 Methods

The objective was to identify and synthesise literature specific to females in football, examining potential differences between pre-season and in-season injury locations, injury types, injury incidence rates, injury burden, and the impact of maturation on these factors.

Eligibility Criteria

The inclusion boundaries are female, soccer-specific players, pre- versus in-season, prospective cohort studies, English language only, including both adolescents and adults (11-years-old - ≤ 40 years-old), clearly defined injury location, injury type, injury incidence rate and injury burden, minimum of one season of pre- and in-season data, season from August-to-May (pre-season August- September: in-season September-to-May), search conducted from inception of databases to 2nd November 2023, secondary search May 2024. Exclusion criteria include full-

season prospective studies (not dichotomising season into pre- and in-season), international exposures and injuries, inappropriate study designs, mixed sports studies, mixed gender studies male and female, and football season August-to-May (March-to-October schedule e.g. for League of Ireland or Sweden's Allsvenskan April-to-October have longer pre-season phases).

Data Sources and Search Strategy

An extensive search strategy was designed with the input of a specialist sport science subject librarian (J.F.). The PEO Framework (Population, Exposure, Outcome) was used to guide and affirm the research question and key concepts for the inclusion and exclusion criteria. Three relevant databases were searched with pre-determined search terms highlighted below. Databases searched:

- PubMed
- Scopus
- SportDiscus

The following search terms and truncations were used, and terms were combined with 'AND' for:

Female

Female OR women* OR woman OR girl*

Injuries

Injur* OR non-contact OR contact OR soft-tissue OR bon*

Soccer

Soccer OR Football

Pre-season and In-season:

Pre-season* OR Preparatory-phase* OR Preliminary-phase OR Warm-up-phase

In-season OR Competitive-season OR Playing-season OR Periodisation

Maturation

Injur* OR 'Injury Risk' AND Female* OR Girl* OR Wom?n AND Paediatric* OR Adolescent* OR Youth AND Growth OR Peak Height Velocity AND Matur* OR Puberty

The search results were transferred to EndNote ™ 20 in Microsoft Windows. Duplicates were removed prior to exporting to Rayyan™ (https://www.rayyan.ai/). Within Rayyan, inclusion criteria were in place in order to ascertain if articles were included or excluded. Results of the search demonstrated that no articles were suitable for inclusion as they included international exposure injury records, did not distinguish between pre- and in-season injuries with female populations, investigations were within different sports, mixed populations, male populations only and outcome measures. Therefore, discussion is based upon existing literature that considered full-season outcome measures with few dichotomising into pre- and in-season outcomes based within the male population which has led to synthesis of the existing literature.

Results

No articles were identified that dichotomised female soccer player injuries into pre- and in-season for injury locations, injury types, injury incidence rates (IIRs), and injury burden. Further, no studies considered the female soccer player maturation impact across the pre- versus in-season phases.

Conclusions

Research on injury locations, types, incidence rates, and burden is advancing for the female population. However, prospective studies that divide the full season into pre-season and in-season are necessary to determine if differences exist between these phases. Studies with

male cohorts have shown variations between pre-season and in-season injury categories. Therefore, enhancing our understanding of these differences in the female population will help develop gender-specific injury prevention strategies for different season phases.

Justification for Narrative Review

Due to the limited high-quality research conducted within women's soccer and within pre- versus in-season injury categories a narrative review was decidedly the approach of choice to explore the available existing literature. A narrative synthesis was considered to address the broad question of differential injury categories of pre- versus in-season and whether maturation impacts these. Therefore, a generalised discussion addressing what is known of pre- versus in-season injuries will be acknowledged.

3 General Injury Patterns in Female Soccer Players

Knowledge of female soccer injuries is advancing through injury epidemiology studies which have investigated injury burden (Mayhew et al., 2021; Horan et al., 2023; Amundsen et al., 2024; Hallén et al., 2024; Materne et al., 2024). Generally, injuries can be categorised as per mode of onset such as overuse or traumatic injuries and mechanism of injury such as contact or non-contact (Neil, Winkelmann and Edler, 2018; Bahr et al., 2020b; Waldén et al., 2023). Overuse injuries involve the gradual accumulation of kinetic energy over time. It is important to note that there is inconsistency in how these injuries are reported across surveillance studies due to the dichotomy that injuries can result from both accumulated stressors over time and leading to acute presentations (Bahr et al., 2020b). A systematic review conducted in US high school and collegiate sport highlights the variation of the definition of overuse within injury surveillance studies combining the term with chronic, gradual onset and repetitive stress with further articles defining overuse as non-contact (Neil, Winkelmann and Edler, 2018). For

example, hamstring tendinopathy, which develops gradually (overuse), can increase the susceptibility to an acute hamstring tear in a single traumatic event (Opar, Williams and Shield, 2012). The working definition proposed by Neil, Winkelmann and Edler (2018) reports overuse injuries are characterised by an underlying pathogenesis of repetitive microtrauma through a gradual onset mechanism. Traumatic injuries are defined as sudden onset with an identifiable event causing the injury (Bahr et al., 2020b). Non-contact injuries occur without any direct or indirect force from an external source and contact injuries occur due to direct or indirect force from an external source (with further subclassifications whereby a comprehensive overview can be found within Bahr et al. (2020b)). Records and knowledge of this kind inform practitioners on injuries to mitigate risk and help to inform targeted strategies for injury prevention including redirecting resources. Injury surveillance studies and audits are the primary approach to identify injury patterns and trends within specific populations (Bonnie, Fulco and Liverman, 1999).

Injury audits are required to inform research and practitioners of high-risk injuries, identify patterns or trends in injury data, evaluate the effectiveness of current injury prevention strategies which may enhance performance and reduce injuries through targeting efforts into modifying risk factors for specific injury prevention programmes (Windt and Gabbett, 2016; Sprouse et al., 2024). Further to injury prevention programmes, seminal works from van Mechelen, Hlobil and Kemper (1992) highlighted a cyclical four step framework as a sequence of prevention which was extended to Translating Research Into Injury Prevention Practice (TRIPP) a six-stage injury prevention approach (Finch, 2006). The six stages consist of injury surveillance, an aetiology and mechanism of injury record, development of preventive measures, ideal conditions/ scientific evaluation, contextualised intervention descriptions to inform implementation and an evaluation of effectiveness of the preventive measures within context (further reading using TRIPP for individualising injury prevention can be found in this

article (Roe et al., 2017)). Albeit, these foundational prevention models provide a base however, advancements within sports performance, crucial updates of reporting guidelines Fuller et al. (2006) to updated International Olympic Committee guidelines (Bahr et al., 2020b) to sport-specific reporting guidelines (Waldén et al., 2023) have considered the limitations within these dated injury prevention models alongside a plethora of other articles and studies in order to improve the standards of studies and works to come.

Recent studies within nine European leagues, including 26 female teams highlighted that clubs could expect 35 time-loss injuries per season (Amundsen *et al.*, 2024; Hallén *et al.*, 2024). The UEFA Elite Injury Study acknowledges female soccer players and considers several key factors such as competitive level, playing position and the associated frequency and burden of injuries (Hallén et al., 2024). However, the detail and standardisation of injury recording, prevention protocols and other interventions may allow the under- or over-reporting of injuries, e.g. impact the calculations of time lost due to one injury or a combined injury being reported as two separate injuries instead of prioritising the records to the longer-duration/ more severe injury, potentially causing misrepresentation. The Hallén et al. (2024) study used descriptive statistics that reported no differences between hamstring versus quadriceps injuries and reported no patterns of injuries across four-seasons. Materne et al. (2024) recently published a prospective cohort study within a professional female soccer team that elaborated on injury incidence (11.1/1000h showing training injury incidence 8.2/1000h and match injury incidence 23.9/1000h). The study reported a high number (671) of injuries for two seasons within one club. The research team explained that the higher 'medical attention' injury frequency was due to an educational intervention for early assessment and advice to reduce injury impact. When only the time loss injuries were investigated this showed agreement to previous Norwegian, German and Spanish studies (Faude et al., 2006; Tegnander et al., 2008; Larruskain et al., 2018).

The majority of soccer injuries generally occur to the lower limb tissues/joints with upper limb injuries reportedly only representing 3% of injuries within professional male European soccer (Ekstrand *et al.*, 2013). Within women's soccer, it has been reported that the quadriceps muscle group is more frequently injured in comparison to their male counterparts who reported female quadriceps injuries n=25 (IIR: 0.98 (0.67-1.46) versus male quadriceps injuries n=17 (IIR: 0.44 (0.27-0.70) (Rate ratio ((95% CI: 0.44 (0.24-0.82)); P-value=.01) in comparison to hamstring strain injuries were female hamtring strain injuries were n=20 (IIR: 0.79 (0.51-1.22) versus male hamstring strain injury n=59 (IIR: 1.52 (1.18-1.96) (Rate ratio= 1.93 (95% CI: 1.16-3.20; P-value=.01) (Larruskain et al., 2018). Materne *et al.*, (2024) reported quadriceps injury as n=21 (IIR: 3.23 (1.05–7.54) versus hamstrings strain injury as n=4 (IIR: 3.23 (1.05–7.54) while Waldén, Hägglund and Ekstrand (2005b) reported posterior versus anterior thigh strains as 67 v 36 (p,0.0001) of variable severity.

The injury severity impacts upon the recovery time directly impacting the time loss – for young players (U14s and U16s) this impacts developmental milestones and can effectively impact in selection for the starting 11, or, selection for the team overall which could see them being removed from the team (Beech et al., 2022; Beech et al., 2024). For the U21s and SNR squads, effectively this may allow deconditioning or atrophy to occur if the injury is a long-term injury (e.g. ACL-injury), that has required surgery (Collings et al., 2021). In longer term injuries other important considerations are required such as the energy systems that are not being challenged due to potential post-surgery management therefore, it is key to ensure that global fitness, strength and conditioning is applied for the athlete (Burton et al., 2023; Belamjahad et al., 2024). The importance of getting a clear message out for injury audits and prevention is pivotal for the combined efforts to keep players on the pitch prepared physically and psychologically for performance (Emmonds, Heyward and Jones, 2019b).

Differences in anthropometrics between male and female athletes have been shown to exist within a cross-sectional comparison study within professional Brazilian male and female soccer players (Schons et al., 2023). One of the most prevalent differences presented that male height (8.27%; p>0.001; *d*=1.964) and mass (19.99%; p>0.001; *d*=1.592) within the Brazilian comparison study were higher than females. Also, the female soccer players skinfold sums were higher than the males (29.53%; p.0.001; *d*=1.212) demonstrating higher body fat or less muscular constitution. This differentiation of muscular mass within the male cohort may be why the men scored significantly higher in the squat jump, countermovement jump, drop jump, linear sprint at 5m, 10m, 15m and 20m and YoYo IRL 1 performance tests versus women (P>0.001). Potentially, this muscle mass difference (between males and females) may elude to males having stronger, more efficient, performance primed musculoskeletal resilience compared to females as supported by a Bundesliga non-conventional cross-sectional study design (of 29 female players and 53 male players) (de Araújo et al., 2020). To note, the external environment, i.e. the pitches remain the same size meaning that the generally shorter female players have the same game demands as their taller male counterparts. This is reportedly 'harder' on female players due to their physiological short-comings (Pedersen, Aksdal and Stalsberg, 2019) as females have to cover the same distances albeit at reportedly slower paces than males (Schons et al., 2023).

The biomechanics of females has been noted as a contributing factor to increased risk of injury with a wider pelvis increasing the 'Q' angle at the hips, increasing femoral anteversion and increased tibial torsion (Harmon and Ireland, 2000). The increased 'Q' hip angle increases tension through the knee joint, combined with a greater ligament laxity than males (debated that laxity fluctuates throughout the menstrual cycle) and lower hamstrings to quadriceps ratio, whereby females have demonstrated an increased dependence on quadriceps in decelerations compared to posterior chain activation of the hamstrings heightens injury risk (Myer et al.,

2011). A Level III hospital-based observational study reported that a reduced sagittal slope of the tibial spine was an independent risk factor for noncontact anterior cruciate ligament injuries (Wang et al., 2024).

Further, ligamentous laxity, reportedly impacted by hormonal fluctuations within the female cohort may also be a contributory factor for increased risk of ligament and joint structure injury (Chaudhari et al., 2007). When females are fatigued, having returned to training, typical of a pre-season, that may account for higher injury incidence rates of overuse, non-contact injuries and an environment for a 'perfect storm' for ACL injuries (Chappell et al., 2002). Menstrual cycle phase may impact injury risk, although the evidence to support this hypothesis is currently sparse. Key hormones oestrogen and progesterone fluctuate during the female menstrual cycle (Adachi et al., 2008; Barlow et al., 2024b). In the ovulatory phase, a dated prospective cohort study (Wojtys et al., 2002) highlighted a potential impact of elevated oestrogen levels associated with increased ACL-injury risk due to variable collagen metabolism and impaired neuromuscular control (Herzberg et al., 2017). Assuming that hormonal fluctuations continue throughout the season, the pre-season phase of the overall season may create a perfect storm for heightened risks of injuries. To acutely prepare athletes for exercise and maximise their output, priming exercises one-to-twelve hours pre-event are prescribed (Mason et al., 2020). Albeit, longer-term strategies are required to impact neuromuscular movement strategies to make a meaningful difference in a players movement pattern, strategies implemented for at least six-weeks and are included in the season-long programme (Myer et al., 2005).

Female soccer requires intermittent bouts of high-intensity activity throughout training, matches and dedicated strength and conditioning sessions (Randell et al., 2021). The mechanical strain through the hamstrings at maximal velocity has been widely documented to increase the risk of hamstring injury while the athlete is in the terminal swing phase of running

(Ekstrand *et al.*, 2022; Fitzwilliam *et al.*, 2024). Further, these exposures increase the frequency of change in direction in response to an external or internal stimulus associated with soccer training. The knee joint loading is affected by deceleration: acceleration forces which increase the loading through the joints (Dos'Santos et al., 2018; Dos' Santos et al., 2020; Fitzwilliam et al., 2024). This is a likely mechanism for an anterior cruciate ligament (Wahlquist et al.) injury (with the addition of tibial torque and knee abduction), whereby the force through the ACL exceeds that which the tissue can withstand (Beaulieu, Ashton-Miller and Wojtys, 2021).

There is a consensus in the evidence base for female players that joint injuries are the most burdensome, often leading to prolonged absences from soccer-related training, matches, and activities with a median of 292 days lost or an inter-quartile range of 246-334 days lost (Mayhew et al., 2021; Horan et al., 2022; Hallén et al., 2024). However, Materne et al. (2024) reported muscle, cartilage and fracture injuries as the most burdensome in-season injury. Potential reasons for this difference could be due to the single-team cohort and the difference of level of play between amateur, semi-, and professional teams, and differences in training/match volumes and intensities between professional and amateur soccer (Klein et al., 2020). These studies included in-season injuries and have not reported the pre-season data to determine the most burdensome pre-season injuries. To ascertain whether injuries sustained in pre-season recur in-season can lead to great potential to mitigate recurring injuries (Fulton et al., 2014). Studies need to incorporate this pre-season phase so that we may draw conclusions for practice in how to meaningfully utilise pre-season data to impact practice and see a ‘return on investment’ for the injury prevention strategies prescribed (Fuller, 2019).

3 Patterns of Injuries Pre-Season versus In-Season

Research has affirmed soccer injuries are multifactorial and are influenced by internal and external factors such as age, previous injury, gender, exercise load and pre-season status (Parpa and Michaelides, 2022). Pre-season is a preparatory phase to develop the required capacities to meet match demands and perform during the competitive season phase. To plan training effectively, practitioners are required to assess athlete performance via assessments of strength, aerobic and/or anaerobic capacity and potential asymmetries which may be a contributing factor of injuries in-season (Watson et al., 2017). Ekstrand et al. (2020) demonstrated in a descriptive epidemiology study of male European soccer players that increased attendance in pre-season training equated to improved team availability for training and matches for the whole season. This study also highlighted pre-season training reducing severe injury frequency and burden across the whole season by 21.8 days per 1000 hours of exposure, which further demonstrated a greater reduction in time-lost to 24 days per 1000 hours of exposure in the second part of the season. Different European leagues have strict start dates which only allowed inclusion of the teams who followed the 'traditional Western European' schedule (i.e. pre-season commencement in July, in-season beginning in August and off-season beginning in May). This is important to consider, as those teams whose leagues followed a spring to autumn (April to November) schedule resulted in a longer pre-season duration.

A critical paradox exists in injury prevention whereby claims report pre-season is essential for the in-season injury reduction yet report the pre-season to have the highest injury incidence (Windt et al., 2016). Pre-season injury is multifactorial albeit, rapid escalations in loading from off-season to pre-season in a matter of days may be contributing to the heightened injury incidence (Windt and Gabbett, 2016; Windt et al., 2016; Gabbett and Whiteley, 2017). The English women's super league has 22 competitive matches and runs over 24 weeks whereas the men's competitive season in English premiership has 33

competitive matches and can be up to 35 weeks (players selected for European and International matches have more accumulated training and match exposure). Albeit, the sudden return to training load for players who have not been selected for international duty may experience deconditioning/ inadequate conditioning of the off-season or perhaps poorly managed return to play timelines (e.g. players injured in junior academy having to seek external private or NHS professional support) (Le et al., 2025). Pre-season can also be used as a stress test that exposes deficits (in fitness, neuromuscular control, recovery) too abruptly (Ishida et al., 2021).

Pre-season programmes may be flawed in rapid load progression without due diligence to adaptability to smart, progressive loading and violates loading principles (Gabbett and Oetter, 2025). The structure, timing and content may not align with evidence-based principles of load progression and individualization (Brandon, 2015). This may be in part to the focus of the pre-season prioritizing fitness testing/ team tactics over gradual physiological adaptations. The acute: chronic workload ratio may be poorly applied which allows for safe loading progressions per the player's ability and not a uniform prescription of load generically decided for the whole squad which may over or under stimulate players (returning from variable fitness, performance profiles and activity levels i.e. European or International duty) (Griffin et al., 2020; Griffin et al., 2021a; Griffin et al., 2021b). Potentially, this may create survivor bias that observes injury prone players being filtered out early in the pre-season (Grashow et al., 2019). This bias may skew our understanding of the effectiveness of pre-season preparation as those who remain uninjured complete the season phases. Therefore, those who complete the pre-season may appear to be more resilient, artificially making pre-season training seem protective. Potentially the following can lead to risk of increased injury:

- Rapid load escalation

- Generic pre-season programme (One size fits all approach)
- Inadequate screening/ Baseline testing prioritized/ Insufficient monitoring
- Focus on performance and not preparation
- Return to training/ play mismanagement in pre-season

Another UEFA study of longitudinal injury epidemiology in male soccer reports that more pre-season training equates to a 'healthier' in-season player profile, which is supported by findings in a rugby population (Windt et al., 2016), American Football (Murray et al., 2018), and Australian Football (Colby et al., 2017). However, there are few studies in female soccer evaluating injury incidence and burden for pre-season versus in-season injuries albeit with limitations. In an injury observation study in Australian male academy (under-13 to under-18) players displayed higher injury incidence rates during pre-season than at the end of the season, with injury burden demonstrating similar trends (pre-season injury burden reported as 140.9 full days lost/1000 hrs, CI 117.4–169.1 versus in-season burden 69 days/1000h versus the end of season burden 25 days/1000h) (Veith et al., 2023). A German-based study of male academy soccer players supports the claim that injury rates are higher in the pre-season, with overuse injuries being the most commonly reported issue, occurring more frequently (Weishorn et al., 2023). Improved team availability has been associated with greater team success (Hägglund et al., 2013).

However, there remain large discrepancies between the aforementioned studies in male soccer players than those performed in female soccer players. Materne et al. (2024) reported that the in-season injury burden in female soccer players was reported as 370 days per 1000 hours with an average of 33 days lost per injury. A higher in-season injury burden was observed throughout the season in professional female teams, showing 216 days per 1000 hours and an average of

35 days lost per injury in Spain (Larruskain et al., 2018) compared to 468 days per 1000 hours and 58 days lost per injury in England (Mayhew et al., 2021). In contrast, Hallén et al. (2024), who investigated 15 professional female soccer teams across Europe, demonstrated 189 days per 1000 hours in one season, which is markedly lower than the Scottish-based professional team (Materne et al., 2024). However, Hallén et al. (2024) neglected pre-season injury data due to limited access to the players for pre-season exposure. These data suggest that injury burden is influenced by the region and league level of the player. Interestingly, although there is debate regarding physical injury audits and relationships or associations to injury risk and country of training, a study reports cultural impact upon psychological injury (Schinke et al., 2018).

Potential explanations for the discrepancies between studies are based on the methods and inclusion criteria of the studies. Materne et al. (2024) included international duty injuries as well as those injuries that required medical attention (85%; n=570). Also, players within the study by Materne et al. (2024) received education for early attention for minor and gradual onset injuries during season one and at the beginning of season two which may explain the increase in medical attention injury reports. Time-loss injuries (15%; n=101) during the international window (8%; n=8) impacted on the club's total lay-off time (5%; 175 days). Nevertheless, the league change and participation in the Champions League for the first-time increased match congestion during season two with players having to perform in two matches a week. Therefore, less recovery time between training sessions and matches has been associated with an increased likelihood of injurious mechanisms through fatigue and the impact of this on the biomechanics of female soccer players (Zago et al., 2021; Aquino et al., 2022).

Potentially, claims that region can influence burden can derive from differences in coaching systems have been noted to be more aggressive potentially leading to injury risk of injury within European mainland female soccer clubs as demonstrated in a study of 36 elite teams from 17 countries (Ekstrand et al., 2018). Current available literature, in elite male youth soccer

players (Hall et al, 2022) does not support country or region to influence injury risk. Hall et al. (2020) demonstrate injury type and location were similar from four different countries. Hallen *et al.* (2024), the elite female adult soccer study did not stipulate between country or region differences. Emerging evidence denotes contextual factors such as fixture congestion, medical access and player workload management to vary considerably across the leagues which may predispose players to an increased risk of injury. This was described in a professional male soccer population review (Page et al., 2023), another review describes a professional mismatch in ACL-injured female populations to influence injury risk (Le et al., 2025) and an Irish Women's National League reference described gender inequalities with access to subpar facilities, coaching and other contextual factors (e.g. pitches, time of access to pitches, generally later) to heighten risk of injury, each article referring to gender-relative disparities within different female soccer leagues (Horan et al., 2024). Within a one-team Women's National Squad (28 players) study over four tournaments, the days between matches (~3days) reported decreased performance when players had increased time on the pitch and there were ≤3days between matches (Brown et al., 2024). Brown et al. (2024) observed significant gaps in the literature in relation to congested schedules with limited recovery time within female soccer which have all been linked to elevated injury risk (Mayhew et al., 2021).

Limitations include underrepresentation which may be due to limited access to U11s, U12s, U13s female players which Beech et al. (2022) had included albeit, in small numbers. Access would assist to gauge how the peak height velocity (PHV) climates within these age categories differ and how PHV could impact injury and if differences exist between season phases. Females achieve PHV earlier than males (Malina, Bouchard and Bar-Or, 2004; Malina et al., 2005; Malina et al., 2021). A lack of longitudinal studies limit the understanding of injury trends over time and recovery times alongside measuring if prevention methods are effective in pre- and in-season (Prempeh and Pennington, 2025).

Insufficient reporting on injury mechanisms and context as details such as match or training, contact or non-contact, previous injury, recurring injury are not always reported therefore making it difficult to target injury prevention strategies with so many unknowns (Emmonds, Heyward and Jones, 2019b; Arora et al., 2023; Prempeh and Pennington, 2025). The inconsistencies in injury definitions and surveillance methods complicates comparisons between studies which causes limitations in developing robust surveillance systems (Arora et al., 2023). There remains to be limited focus on specific injuries. As research appears to be heavily focused upon anterior cruciate ligament injuries in females (due to burden and sequalae) (Ireland, 2002; Renstrom et al., 2008; Alentorn-Geli et al., 2009; Whittle and Crow, 2009; Dragoo et al., 2011b; Littmann et al., 2012; De Ste Croix et al., 2015; Anh-Dung et al., 2017; Herzberg et al., 2017; Lamond et al., 2018; Collings et al., 2021; Taghizadeh Kerman et al., 2023; Le et al., 2025), other common injuries such as quadriceps, hamstrings, triceps surae, concussion or over-use injuries are under-studied.

Despite the growing body of research, the differences in injury patterns between pre-season and in-season remain underexplored. Various methods of standardization and the inclusion of players across different levels, domestic club soccer and tournament soccer have provided useful insights into injury trends across league tiers. The use of medical attention and time-loss injuries influences the overall reported percentages of injuries, which can lead to erroneous interpretations. Nevertheless, it is important to consider injuries which require medical attention and importantly those which cause time loss, so that injury severity may be calculated, including further research focusing on injury patterns relative to seasonal phases. Male cohorts have demonstrated that increased pre-season participation can reduce the frequency and burden of in-season injuries, suggesting that a similar approach could be effective for female cohorts.

4 Other Prominent Key Factors In Female Soccer Players

Recommendations and suggestions of female athlete rehabilitation and prevention programmes have originated from research conducted with male participants (Emmonds, Heyward and Jones, 2019a). However, there are important physiological differences between males and females which potentially impact upon injury risk factors and aetiology (Dragoo et al., 2011a; Datson et al., 2014; Beech et al., 2022; Larruskain et al., 2023). Differences in metabolic, anatomical and physiological components unique to female athletes must be considered (Bell et al., 2014; Moore et al., 2023). Of note, the menstrual cycle is a key influence upon injuries as hormonal fluctuations occur through the cycle, and a recent study highlighted the luteal phase to have an increased risk of injuries (Barlow *et al.*, 2024). The cyclical variations of hormones have an impact upon musculoskeletal tissues such as muscles, tendons and ligaments (Chidi-Ogbolu and Baar, 2019). Research has indicated that the late follicular phase also referred to as the pre-ovulatory phase has an increased risk of anterior cruciate ligament injury which contrasts with previously mentioned luteal phases (Hewett, Zazulak and Myer, 2007; Dos'Santos *et al.*, 2023). The menstrual cycle is beyond the scope of this chapter; however, it is acknowledged as a physiological factor that may influence injury risk in female soccer players (further reading regarding menstrual cycle influence on injury: A systematic review of general sports injuries and menstrual cycle (Martínez-Fortuny et al., 2023); a recent prospective soccer-specific women's premiership level cohort study over three seasons (Barlow et al., 2024a) and, a four year soccer-specific prospective cohort study at international level (Martin et al., 2021).

Psychosocial Focus

The psychosocial and psychological factors are neglected to an extent which in pre- versus in-season injury audits is important as pre-season players may not have the same spectator/

sponsorship pressure however, they will be competing to be part of the starting 11 squad for in-season (Abbott et al., 2019). Pre-season versus in-season psychosocial factors studies are sparse in the male cohort with fewer still in the female cohorts, further research is required.

Biomechanics Focus

Biomechanics pre-season should focus upon preparation for performance and not performance for testing like male pre-seasons. Pre-season ultimately prepares athletes through a return to sporting activity and allowing for familiarisation of sporting and performing tasks to be refreshed following a period of off-season and assessments can be applied for performance (Oliveira et al., 2024). Without proper progressions in training content, high biomechanical loads are placed upon the female players body prior to appropriate neuromuscular control of the trunk, hips and knees are optimised (Belamjahad et al., 2024). To maximise performance in athletes within 1-12 hours prior to performance priming exercises can be implemented (Mason et al., 2020), however, for longer term movement strategies for longer term movement adaptation to prevent potential severe injuries such as the ACL requires up to six weeks for neuromuscular benefits/ control (Belamjahad et al., 2024).

Females generally demonstrate greater knee valgus, hip internal rotation and quadriceps dominance, (Ford et al., 2011; Abián et al., 2021; Andrade et al., 2021) which has been reported to be impacted further when females are fatigued, that may account for higher injury incidence rates of non-contact, overuse injuries, an environment for a ‘perfect storm’ for ACL injuries (Chappell et al., 2002). Furthermore, females wider pelvis-to-femur Q-angle increases tensioning forces through the knee joint, a greater ligament laxity than males (debated that laxity fluctuates throughout the menstrual cycle) and lower hamstrings to quadriceps ratio whereby females have demonstrated an increased dependence on quadriceps

in decelerations compared to posterior chain activation of the hamstrings influences injury risk (Ford et al., 2011; Myer et al., 2011). Potentially these exaggerated movement biomechanics are partially due to a lack of structured and monitored strength and conditioning programmes, hormonal fluctuations in non-competitive off-season being different to in-season and the deconditioning of the stabilising musculature during the off-season phase (Reiman and Lorenz, 2011). As acute exposure develops over time and becomes chronic the body adapts to training and match environments to prepare for in-season demands, this may allow for improved neuromuscular efficiency and postural control through the repeated sport-specific movement exposure (Windt et al., 2016; Gabbett and Whiteley, 2017). Technical staff may introduce corrective measures following the baseline testing which, being applied sooner in the pre-season phase allows for meaningful adaptation to occur over time and it is envisaged that this time produces a buffering protective element to reduce the likelihood of individual specific injuries or recurrences for in-season (Bonacci et al., 2009; Diekfuss et al., 2020).

Footwear Focus

Footwear is often and overlooked yet plays a vitally important part of a players toolkit (Blanchard et al., 2018). Pre-season may introduce a surface-footwear mismatch whereby teams are training in warmer, drier climates, or upon synthetic surfaces with limited access to grass meaning that the surfaces are harder, or drier, even those with watering management systems (Thomson, Whiteley and Bleakley, 2015), in turn increasing ground reaction forces and torsional resistance (Frederick, 1986; Nigg et al., 2012). Due to costs incurred through attaining different boots for different surfaces in younger academy groups costs may be too expensive for parents to continue buying new boots/ adapted boots for different surfaces for their growing children and especially if they have more than one, hand-me-down boots that

are over-worn and eligible for the bin are utilised, sustainability versus heightened injury risk (Ludin et al., 2025). Players maintain to wear the same boots as the competitive in-season phase which are ultimately boots optimized to be played in upon softer, well-maintained pitches (Lambson, Barnhill and Higgins, 1996). Insufficient footwear rotation depending on surfaces played upon (grass, artificial or indoor increases cumulative loading which can compound injury risk factors (Karolidis, Denton and Hahn, 2025). With this in mind, there remains to be a gender bias of footwear for the male foot morphology, which tends to differ from the female foot in the arch, width and volume (Althoff and Hennig, 2014).

4.1 Influence of Biological Maturation on Injuries in Female Soccer Players

Maturation in youth athletes is defined as the process of physical, hormonal, and developmental changes that occur as they progress toward adulthood, influencing growth, physical performance and susceptibility to injury (Towlson et al., 2021). Growth and maturation are not linear processes. Chronological age is defined as the amount of time that has lapsed from birth (Lloyd et al., 2014), whereas biological age accounts for the stage of physical maturity and can explain interindividual variance between athletes (Malina, Bouchard and Bar-Or, 2004). Youth athletes may be early, normal or late maturing but during this process, immature/ vulnerable structures exist i.e. the brain, cartilage and physis/ epiphyseal plates (Jones, Wolf and Herman, 2017). An example of a common youth-related injury (commonly occurring in females aged between 8-12years old) would be Osgood Schlatter's disease which can be managed through pain relief, rest, ice, compression and elevation with modified activity through to a progressive return to training and to sport (Smith and Varacallo, 2017). A range of maturity indicators exist and are used within the literature that range from skeletal age, age at menarche, percentage of adult height, predicted maturity offset and stages of pubertal growth (Lloyd et al., 2014). The Tanner scale classifies stages of pubertal growth in males and females that assist in the

assessment of which stage of puberty they are experiencing (Hamlin, Robertson and Wilson, 2022).

A commonly reported injury mechanism related to maturation is adolescent awkwardness which is the reduction in kinaesthetic awareness due to a rapid increase in stature and limb length (John et al., 2019). During rapid growth, there is increased tension between the muscle-tendon unit and secondary centres of growth on the bone which can lead to pain and at times avulsion injuries if a rapid movement occurs (McKay, Broderick and Steinbeck, 2016). Maturation should be monitored and strategies to facilitate growth spurts to ease the impact of these processes on soft tissue may reduce the time loss from sport. Albeit, during any stage of maturation and/or growth, be it pre-, in-season or off-season a player is encouraged to train as matches and training sessions cannot be changed to suit any one player's symptoms.

While maturation has been associated to a primary risk factor in adolescent female soccer players, players within age groups of under-14s and under-16s may be beyond peak height velocity (Malina, Bouchard and Bar-Or, 2004). Players who have achieved full peak height velocity may not have necessarily have achieved full physical or neuromuscular maturity as a chronological age and maturation study conducted in a male soccer cohort demonstrated (Read et al., 2018b).

4.2 Influence of Player Position on Injuries in Female Soccer Players

Positional roles exist within an 11-player soccer team with some studies referring to generic roles such as goalkeepers, defenders, midfielders and forwards neglecting nuance within positions. Specific positions require bespoke tactical roles (Martínez-Lagunas, Niessen and Hartmann, 2014) and these specific roles result in significantly different external load/ running demands, which could influence injury location and frequency (Clemente et al., 2013; Abbott,

Brickley and Smeeton, 2018; Hall et al., 2022b). A study conducted on German female soccer players reports that defenders (9.4 injuries per 1000 h) and strikers (8.4 injuries per 1000 h) had considerably higher IIRs in comparison to goalkeepers (4.8 injuries/ 1000 h) and midfielders (4.6 injuries/ 1000 h) (Faude et al., 2006).

The difference between these positions may be due to the distances covered by the different players in these positions. Lateral players have been observed to perform more accelerations and decelerations in elite Danish male soccer teams (Vigh-Larsen, Dalgas and Andersen, 2018) with a Norwegian male soccer study agreeable with this claim (Ingebrigtsen et al. (2015). Position-specific injury prevention should be applied. The need to extrapolate data to inform pre-season training to reduce injury likelihood, severity and burden is required to enable effective injury prevention. Reportedly, female players typically perform high-speed running (16-20km·h^{-1}) and sprinting (>20km·h^{-1}) (Griffin et al., 2021b), lateral players perform more sprinting during matches which may contribute to the multifactorial risk of hamstring injuries. Hamstring injuries are widely reported with high-speed running and sprint biomechanics as some of the risk factors (Maniar et al., 2020) as well as previous injury. Forwards and defenders within male cohorts demonstrate higher injury burden in matches, while training injuries are observed to be higher in wide and midfield players (Choi and Joo, 2022; Hall et al., 2022b). The differences observed may be due to the repeated, sprinting demands of forwards to evade defenders that could lead to non-contact muscle strain injuries in the hamstring muscle group or perhaps the increased contact injuries of defenders who intervene in a forward's attempts to get the ball into a 'scoring position' (Hawkins and Fuller, 1999; Faude et al., 2006; Hall et al., 2022b). Midfielders typically cover greater distances at varied intensities putting them at increased risk of overuse injuries in pre-season when aerobic conditioning and speed drills are emphasised (Mohr, Krustrup and Bangsbo, 2003). In contrast, the defenders and goalkeepers are subject to high-impact collisions and explosive

movements (Alentorn-Geli et al., 2009; Della Villa et al., 2020), potentially predisposing them to acute traumatic injuries, especially in-season when match frequency increases in youth athletes (Brenner et al., 2024), female youth soccer athletes (O'Kane et al., 2017), male professional soccer players (Page et al., 2023) and within a female soccer team (German league) (Faude et al., 2006). Moreover, the tactical changes that occur in-season may put increased demands on certain players in key positions, additionally, if foul play leads to a player being removed from play bestows responsibility on players to cover more area in defending or attacking areas with one less player. Furthermore, during in-season competitive matches if a player is abruptly substituted into play without prior warning and adequate warming-up pitch-side could theoretically increase the risk of injury. This creates a change in the formation of teams and pressing/ defending on intensity the other players incur; therefore, movement patterns can become altered alongside reduced recovery windows within competitive matches further influencing the injury profiles by position. Consequently, interpretation of injury surveillance data must consider the positional variability, particularly when it comes to analysing incidence, burden and severity as these do not appear to be evenly distributed across the positional roles on the pitch (Bloomfield, Polman and O'Donoghue, 2007; Hall et al., 2022b).

A limitation of detailed positional analysis, the aggregation of injury data across positional roles may obscure injury trends related to risk, severity and recovery. Positional data were available however, it was deemed beyond the remit of this level of investigation as the question focused upon the pre- and in-season injury characteristics across female soccer demographics and therefore the analysis that was carried out was removed. Granular conclusions regarding positional roles were therefore not reported as part of this thesis. The future efforts of positional influenced injuries should be reported as per injury incidence

rates, burden, severity and when in the seasonal calendar so resources can be dedicated and position-specific to tailor prevention strategies effectively.

Player position is an important factor that can demonstrate differences in injury profiles related to performance requirements (Abbott, Brickley and Smeeton, 2018). Further research into player position-specific injuries remains to receive clarity for pre- versus in-season so injury prevention strategies may be implemented.

5 Conclusion

A crucial issue in the field of women's soccer research is the reliance on findings and guidelines initially developed for male soccer players. The majority of pre- versus in-season injury investigations are based on male athletes, and these suggest a higher risk of injury in pre-season. Lower limb injuries dominate soccer injury audits in female populations, with the ACL injury reported as the most burdensome. Female cohorts endure more overuse injuries in pre-season versus in-season although further investigations are required to make appropriate recommendations for injury prevention strategies (Coppalle *et al*, 2019).

It is unclear if injury patterns exist between pre-season and in-season in female soccer players due to the focus on in-season and the heterogeneity of studies. Further, it is difficult to conclude whether adult and youth female athletes reflect similar or different injury patterns. Thus, further research is required in this area.

6 Practical Implications

Consensus is required for recording and reporting injuries within pre- and in-season soccer, particularly with regards to women's soccer, for which there is currently just one study that has investigated this important question. Newly published soccer-specific guidelines were

published to facilitate injury audits (Waldén et al., 2023), and it may take time to see the benefits of these newly introduced guidelines. The seminal guidelines (Fuller et al., 2006) acknowledged the methodology of epidemiological studies whereas the updated guidelines provide football specific terminology and suggest more injury time bins to establish enhanced capabilities of categorising injury severity, with emphasis on reporting the injury burden which considers the injury incidence and severity of injuries with further elaborations of injury locations i.e. groin. Further, the Waldén et al. (2023) guidelines define categories of return to football following ill-health and highlight the importance of match and peri-match exposures. It is unknown if female soccer players have a higher prevalence of quadriceps injuries due to the injury prevention strategies that may have been implemented due to the evidence that has been shared through male soccer research findings. Finally, there is a knowledge gap that requires further research in order to understand and detail pre- versus in-season injury patterns, incidence, burden and phases of the season in which targeted strategies would have the most meaningful impact.

This thesis plans to address the limitations above through a gender-specific population (females) within soccer to add depth to the underrepresented population. Through utilising the updated reporting guidelines to ensure reporting standards will be of good quality to aid in the comparability to other studies (Walden et al. 2023). Through using injury incidence rates, burden and severity will assist in contextual analysis through reporting on the GPS training and match loads when the GPS data was available. The study can help to highlight the neglected pre- vs in-season injury differences and compare how these differ between U21s and SNR squads and overall season comparisons between U14s, U16s, U21s and SNR squads.

This thesis contributes to the female soccer injury literature by:

- Prioritizing gender-specific data collection and analysis;
- Standardizing injury reporting methods to enhance future research comparability;
- Incorporating context-sensitive variables often excluded from traditional injury studies.

Chapter 3: An Injury Audit in Women's Professional and Academy Soccer: A Comparison of Pre- versus In-Season Injuries

Abstract

The aim of this injury audit was to investigate the characteristics of injuries during pre- and in-season in women's professional clubs and academies in England and Spain over two seasons.

Methods

This prospective study included 305 female soccer players (12-43 years old) recruited from four soccer clubs/academies in England and Spain in the 2021-22 and 2022-23 seasons. The soccer clubs' medical and sport science teams diagnosed injuries, while training and match hours were recorded via Global Positioning System or coaches' records. Players were categorised into four squad groups according to their age/playing level: (i) Under 14s (U14s); (ii) U16s; (iii) U21s; and (iv) senior squads. Injury incidence rate (IIR, i.e. injuries per 1000h) and burden (i.e. IIR × days lost) were calculated for overall U14s and U16s squads and the U21s and SNR squads were compared between pre- and in-season, and between squad groups. Severity was reported number of days lost.

Results

Overall, 308 injuries were recorded from 419 player seasons. For the senior players, muscular IIR was higher during pre-season (2.17 [95% CI: 1.38-3.41] injuries/1000h) vs. in-season (1.06 [95% CI: 0.75-1.51] injuries/1000h; $p<0.05$). Similarly, thigh IIR was higher during pre-season (1.24 [95% CI: 0.67-2.28] injuries/1000h) vs. in-season (0.45 [95% CI: 0.26-0.77] injuries/1000h; $p<0.05$). Regarding the U21 players, ligament/tendon IIR was higher in pre-season (4.06 [95% CI: 1.15–14.39] injuries/1000h) vs. in-season (0.96 [95% CI: 0.43–2.14] injuries/1000h; $p<0.05$). A similar pattern was seen regarding knee IIR in pre-season (4.06

[95% CI: 1.02–16.24 injuries/1000h) vs. in-season (0.64 [95% CI: 0.24–1.71] injuries/1000h). Concerning the between age-group analyses, both IIR and burden tended to increase with advancing age for most injury types/locations but then decreased in the senior players. The quadriceps was the most frequently injured muscle pre-season (66.7%), while the triceps surae was the most frequent muscular injury in-season (25.3%). Muscular injuries were most frequent in pre-season for the senior squads while ligament sprains were most frequent for the U21s, with the highest burden. During in-season, muscular and ligament injuries were most frequent across all squads with ligaments most burdensome.

Conclusion

Muscle and thigh IIR were higher in pre-season than in-season for the senior players, while knee and ligament/tendon IIR was higher in pre-season than in-season for the U21 players. Injury burden appeared to increase with advancing age but was lower in the senior squads compared to U21 and U16. This study highlights the need for demographic-specific strategies regarding injury prevention in pre-season vs. in-season, as well as according to age group.

Introduction

Female soccer has seen a rapid increase in participation and professionalism over the last decade (Kirkendall and Krustrup, 2022). As such, attention to injuries and how to mitigate and manage injuries within this population is crucial in supporting female soccer athletes (Chandran *et al.*, 2021; Barlow *et al.*, 2024). An injury audit provides stakeholders with evidence to elucidate potential risk factors that can subsequently be managed by evidence-based changes in training/recovery to reduce injury risk. Injury prevention models have been established in order to mitigate the occurrence of injuries such as the van Mechelen, Hlobil and Kemper (1992) model. Numerous injury audits have been performed in men's professional (Woods *et al.*, 2002; Hägglund *et al.,* 2009; Kristenson *et al.*, 2016; Fitzharris *et al.*, 2017; Dönmez *et al.*, 2020; Della Villa *et al.*, 2020; Page *et al.*, 2023) and men's academy (Brito et al., 2012; Read et al., 2018a; Hall et al., 2020; Materne et al., 2020; Raya-González et al., 2020; Wik et al., 2020; Veith et al., 2023; Weishorn et al., 2023) soccer but fewer audits have been performed in women's professional (Giza et al., 2005; Del Coso, Herrero and Salinero, 2018; Larruskain et al., 2018; Horan et al., 2022; Gasparin et al., 2024) and women's academy (Söderman et al., 2001; Le Gall, Carling and Reilly, 2008; Beech et al., 2022) soccer and one combined (senior and academy player) study (Farley et al., 2022). Conducting injury audits in women's soccer is vital due to the differences in physiology, anatomy, biomechanics (Mayhew et al., 2021), training and match demands (Porras *et al.*, 2022), and the evidence for differences in injury risk (Hägglund *et al*., 2009; Larruskain *et al*., 2018) between female and male players.

Injury history is important to consider throughout an athlete's career, as previous injury is known to be one of the largest risk factors for subsequent injury (Kyritsis et al., 2016). Player availability can acutely influence the outcomes of matches and tournaments (Parry and Drust,

2006; Ekstrand, Hägglund and Waldén, 2011; Hägglund *et al.*, 2013), and the demand on uninjured players may be increased in covering injured players' positions, thus increasing their risk of injury (Clemente *et al.*, 2020; Maneiro *et al.*, 2020). Player availability affects not only match results due to player absence but also the progression of academy players by causing missed development time. As highlighted by Larruskain et al. (2022), this presents an additional challenge for developing players. Therefore, identifying common injuries that have the greatest impact on player availability should aid in future injury management. Further, it is important to consider infrequent injuries with a higher severity, as these may be career threatening. This may result in long-term repercussions for the younger athlete, as players who injure their anterior cruciate ligament (Wahlquist et al.) are more likely to have a subsequent ACL injury (Della Villa *et al*, 2020).

The injury patterns identified within male academy cohorts generally demonstrate higher incidence rate with advancing age (Hall et al., 2022a). Regarding female soccer players, relevant studies conducted within a Spanish senior female cohort (Del Coso, Herrero and Salinero, 2018) reported on the proportion of injuries sustained during matches compared to training, and highlighted a higher incidence and severity of non-contact than contact injuries in players aged 18 years and over. Beech et al. (2022) found that injury incidence rate (IIR, injury frequency per 1000 h exposure), injury severity (number of days' absence) and injury burden (IIR × injury severity) increased with advancing chronological age in players from six women's soccer academies in England. However, the aforementioned studies grouped pre-season and in-season data together, so it was not possible to discern if injury patterns differed between pre- and in-season, which may be an important problem considering the higher IIR in pre-season compared to in-season in professional male Swedish players (Waldén, Hägglund and Ekstrand, 2005a). This was reflected in a higher IIR in pre-season than in-season in

Australian male academy players (Veith et al., 2023), and overuse injuries being the most commonly reported type of injury during pre-season in male German academy players (Weishorn et al., 2023). Regarding women's soccer, however, only one study has investigated differences in IIR and injury burden between pre- and in-season, with no obvious pattern detected over four consecutive seasons in professional female soccer players (Hallén et al., 2024). However, certain limitations (such as between club differences in injury reporting, data loss pertaining to mechanism of injury may impact on IIR) may have confounded any differences between pre- and in-season. Thus, detailed and comprehensive analysis is required to investigate this important research question in female soccer players. Such knowledge could help inform injury prevention strategies during potentially high-risk periods of women's soccer.

Interestingly, the UEFA injury study by Hallén et al. (2024) does not report injury patterns over the four consecutive seasons studied which may elude to the European squad selection of 'fit' players whereby potentially there is survivor bias present in the players represented in the cohort of players. The focal point is adult level which does not include younger age groups which the present study has included. Furthermore, players at this level are recruited from many teams who have different pre-season and in-season strategies that have not been reported, questions would need to ask about the practice of pre- and in-season strategies practiced at those clubs. A noteworthy contrast of the present study to the Hallén et al. (2024) study, a consistent spike in injury incidence was observed across season phases for the U21s. This discrepancy highlights several important questions regarding differences between contextual, methodological and demographic differences between cohorts. One potential explanation may be that due to Hallen et al (2024) study being conducted in adults is that they have more structured and evidence-based practices applied in pre-season, content of those programmes having individualized load monitoring, periodized conditioning and

injury prevention strategies. However, the study does not report on pre- or in-season training as at European level, these strategies are normally executed within clubs therefore we do not know the player preparation/ preparedness. Furthermore, it is paradoxical whereby increased injury rates during pre-season are predicted to be higher and protect against injury risk in-season. The acute: chronic workload ratio describes progressive time-scales to allow for adaptability for the body to respond to a stimulus (Windt et al., 2016; Gabbett and Whiteley, 2017; Gabbett and Oetter, 2025). This does not appear to affect only female soccer athletes as this has been demonstrated in male cohorts (Windt et al., 2016). It appears that current structure, timing and load progressions are insufficiently aligned with player readiness, particularly in developmental squads. It can be concluded that the pre-season phase, rather than be a protective buffer is a period of vulnerability, especially where neuromuscular deficits, biomechanical risk factors and incomplete maturation are present. This underscores the need to reconceptualise pre-season not simply as a high-load preparatory phase, but as a targeted intervention window within the broader injury prevention efforts.

The aim of this study is to determine how injury incidence, burden, type and severity differ between pre- and in-season periods across female soccer players at different developmental stages (U14s, U16s, U21s, and SNR-teams). These efforts aim to highlight key women's soccer injuries, so age-appropriate, phase-dependent injury prevention and training periodization models are informed and targeted for the high injury incidence and heightened injury burdens reported in female soccer cohorts. We hypothesised that IIR and burden would be higher in pre- versus in-season, and that IIR and burden would increase with advancing chronological age (peaking in senior squads).

Aims and Objectives:

1. To investigate injury incidence, burden and severity between pre- and in-season phases within and between each age group (U14s, U16s, U21s, and SNR-teams).
2. To compare injury type and anatomical location between pre- and in-season phases.

Materials and Methods

Participants

Participants were high-level female soccer players aged 12-43 years old from four professional soccer clubs, including senior squads and their associated academies. The cohort included 305 players segregated into the senior squads (SNR), the U21 squads (U21s), the U16 squads (U16s) and the U14 squads (U14s). Table 1 highlights player squad contributions.

Participants Clubs

At the time of data collection, the senior squads of three clubs were competing in the Football Association's (FA) Women's Super League (WSL), the highest league of women's soccer in England, while three senior squads from one Spanish club were competing in the top three divisions of the Spanish professional league (i.e. Primera División, Primera Federación and Segunda Federación). Academy players were recruited from the Spanish club and two of the three English clubs, and included the Under 21 (U21), U16 and U14 age groups. These academies were part of the Regional Talent Pathway in England. There is no classification system for soccer academies in Spain, but the academy included in this audit is recognised as one of the most successful in the country and included the U16s and U14s age-groups. The participants' characteristics are presented in Table 1.

Recording of Soccer Exposure

Training and match minutes were recorded via Global Positioning Systems (GPS) for two English senior squads and the two Under-21s squads. GPS was recorded for the three Spanish senior squads (The three Spanish teams age groups were similar to the first teams within the English Premiership teams and as they perform within highly competitive leagues within Spain were of the same calibre of training and match exposures and therefore were justified to be included in the comparison with the English First-Team squads) and the minutes for the U16s and U14s squads were reported through coaching records for training and match minutes. Overall exposure time was given for the Spanish U14s and U16s squads however, these minutes were not dichotomised into *pre*- and *in*-season therefore overall IIRs are presented. The English U14s and U16s had no official hours or times provided with the coach records only providing attendance information without athlete-specific activities such as training, rehabilitation, educational evenings, alongside transitioning into a new English Female Pathway Framework. Written informed consent was obtained from all participants aged ≥18 years, and parental/guardian consent (and participant ascent) was obtained for participants aged <18 years old.

Ethical Approval

The study was approved by Liverpool John Moore's University Research Ethics Committee (approval reference: 21/SPS/028) and complied with the Declaration of Helsinki.

Table 1: Characteristics of all consenting players in England and Spain Professional Clubs and Academies (Means are ±SD)

Age Group	Player Seasons (%)	Age (years)	Height (m)	Body Mass (kg)
Under 14s	31 (10%)	13.1±0.6	1.57±0.04	49.8±6.5
Under 16s	33 (11%)	15.1±0.6	1.63±0.05	56.9±4.8
Under 21s	53 (17%)	17.3±1.1	1.64±0.05	60.1±6.9
Senior squads	188 (62%)	23.0±5.6	1.67±0.16	61.1±6.9

Study Design/Period

Prospective cohort study. Data collection took place during the 2021-22 season (hereafter referred to as Season 1) and the 2022-23 season (hereafter referred to as Season 2). The prospective design adds strength to minimize recall bias, detailed data collection, generalizability, multiple outcomes could be generated providing a more holistic review of the impact of the exposure. Although, there is potential for attrition bias as those who do not injure in pre-season and fulfil the season could potentially bias the results as those who endure a long-term injury are out for the full season e.g. ACL-injuries, known as survivor bias. The susceptibility for confounding factors whereby it can be difficult to account for all of the potential influences on the outcomes. Table 1B demonstrates the contribution of players in Season 1, and those who continued into Season 2 from the different demographic groups across the two seasons. There were 419 player seasons in total. No other age group stratifications were considered as these were the age-groups that the clubs had categorized

their players into. For generalizations, it was deemed appropriate to keep these age groups as they were.

Table 1B: Tracking of players throughout the study

Teams:	Number of Players Altogether	Season 1: Number of Players	Number of Players Continue to Season 2	Season 2: Number of Players
SNR	188	133	68	123
U21s	53	28	19	44
U16s	33	33	18	18
U14s	31	21	19	19

Recording of Injury and Definitions

Injury reporting guidelines for soccer have recently been updated from the Fédération Internationale de Football Association (FIFA) consensus (Fuller et al. 2006) to a soccer-specific extension (Waldén et al., 2023) which this study followed the latter mentioned guidelines of the most recent International Olympics Committee (IOC) consensus for injury reporting guidelines (Bahr et al., 2020). Injuries that occurred during match play and training were diagnosed and recorded by medical personnel within each of the clubs. The club personnel were provided with instructions from the research team on how injury, exposure and anthropometric data were to be collected. An injury was included in this study if it

prevented the player from participating in training, a match or gym-related activities for 24 hours or more following the onset of injury. The ≥24-hour injury definition is sufficient to capture injuries that cause functional impairment that requires time off and is supported by the updated IOC injury reporting guidelines by Walden et al (2023), ensuring consistency with widely adopted epidemiological studies to allow for comparisons. However, it may lead to an underestimation of minor injuries that require medical attention that do not lead to full absence from training or match play e.g. minor wounds or soft tissue impacts. To reduce the number of hours to ≥1-hour or medical attention injuries could increase the detection of lower severity injuries or reduced data reliability due to inconsistencies in monitoring or self-reporting. Additionally, a lower threshold could lead to overestimation of minor injuries, therefore the ≥24-hours is a pragmatic cut-off value.

Injury incidence rate (IIR) quantified the number of injuries per 1000 h training and match (combined) exposure. Injury severity was defined as the total number of days absent from the date of injury (day zero) to the date of return to full training and/or playing matches. Injury burden was calculated as the median number of days lost multiplied by the number of those injuries per 1000 h exposure (i.e. IIR × severity). Injuries were classified according to location (e.g. hip, knee, ankle) and type (e.g. muscle, tendon, ligament, bone).

Statistical analyses

All statistical analyses were performed using RStudio (version 2024.12.0.467). The Pearson dispersion statistic was used to determine the presence of over-dispersion. As over-dispersion (i.e., the Pearson dispersion statistic > 1.2) in Poisson regression increases the risk of type I error (Payne et al., 2018), negative binomial regression was applied to all IIR and injury burden in all squads. This improved the model fit and reduced the risk of underestimating

standard errors, which could otherwise lead to spurious statistical significance. To account for individual exposure (match or training hours) further strengthened the model's applicability to injury incidence, allowing for accurate estimations across pre- and in-season alongside age categories.

However, zero-inflated negative binomial regression was used only for the U21 squads to compare IIR and burden between pre- and in-season due to errors generated with negative binomial regression (likely due to the limited U21 sample size). A zero-inflated negative binomial regression (ZINB) was applied to the U21s category for the excessive number of '0'/ zero injury observations that the standard negative binomial regression could not explain. Potentially, certain players within the U21s squad were inherently at a reduced risk of injury due to either low match minutes, conservative return to play protocols or exceptional neuromuscular resilience placing those players into a 'zero' group (individuals who were never at risk of injury during study). Albeit model diagnostics revealed a high number of zero counts alongside over dispersed data which demonstrated that the model outperformed the standard model in terms of fit. The zero-inflation model effectively allowed a dual approach 1) a count generating process for players at risk and 2) a separate process that generated 'certain zeros' for those not at risk. Acknowledging this duality was essential to avoid biased estimations of injury incidence so interventions could be adequately targeted.

To compare IIR and injury burden between age groups, rate ratios and their 95% CI were calculated to test statistical significance using *z*-statics (Monasterio et al., 2022). The significance level was set at $p < 0.05$.

It should be noted that for the younger academy categories (U14s and U16s) the appropriate club staff were contacted in relation to missing data. However, not all data was received therefore the records had to be assigned an 'unknown' label and this was as count data.

The high proportion of unknown injury mechanisms makes it difficult to draw definitive conclusions about causality and reduces how specific preventive interventions can be. This under-reporting reflects the challenges of injury surveillance accuracy therefore, education surrounding injury surveillance should be provided to staff and players alike to aid capturing meaningful injury data.

Results

Injury Summary

A total of 342 injuries were recorded over both seasons. Of those injuries, 34 were excluded as they did not occur with the club (n=11), were unrelated to soccer (n=8), occurred during international duty (n=11) and some did not meet the minimum time loss from the sport, i.e. ≤1 day of absence (n=4). This resulted in 308 injuries being eligible for inclusion for statistical analysis for the entire season. The U14s and U16s squad exposure records did not distinguish between training and matches or *pre*-and *in*-season, thus training and match exposure was pooled for each squad group to enable comparisons between squad type for the entire season (Table 2).

Injury Incidence Rates

Table 2 Overall Injury Incidence Rates (IIRs) including upper and lower 95% confidence intervals (CI) in all squads with exposure records (n = 305 participants).

	Senior squad[§]					**U21 squad**					**U16 squad**		**U14 squad**	
n (% cohort)	188 (62)					53 (17)					33 (11)		31 (10)	
Exposure (hours)														
Total	49,247					7,228					5,600		7,813	
Pre-season	10,117					985								
In-season	39,130					6,243								
Season period	**Pre-season**		**In-season**[§]		**Entire season**	**Pre-season**		**In-season**		**Entire season**	**Entire season**		**Entire season**	
Injury category	**Frequency**	**IIR (95% CI)**	**Frequency**	**IIR (95% CI)**	**Overall IIR (95% CI)**	**Frequency**	**IIR (95% CI)**	**Frequency**	**IIR (95% CI)**	**Overall IIR (95% CI)**	**Frequency**	**IIR (95% CI)**	**Frequency**	**IIR (95% CI)**
Overall	43	4.51 (3.26–6.22)	115	3.19 (2.56–3.99)	3.57 (2.96–4.30)	10	16.58 (7.42–37.04)	27	8.03(3.88–16.62)	6.00 (3.96–9.10)[b*,f*]	31	6.62 (4.05–10.82)[c*, g*]	22	2.98 (1.73–5.13)
Muscle	21	2.17 (1.38–3.41)[a*]	40	1.06 (0.75–1.51)	1.34 (1.01–1.78)	2	5.70 (1.15–28.28)	11	5.43 (1.52–19.48)	1.89 (0.97–3.68)	7	1.28 (0.53–3.11)	6	0.77 (0.30–1.96)
Ligament/tendon	11	1.14 (0.62–2.11)	35	0.96 (0.65–1.40)	1.00 (0.72–1.39)	4	4.06 (1.15–14.39) [a*]	6	0.96 (0.43–2.14)	1.56 (0.74–3.27)	14	3.11 (1.50–6.47)[c†, g*]	6	0.79 (0.30–2.06)
Bone	2	0.20 (0.05–0.81)	12	0.32 (0.17–0.59)	0.29 (0.17–0.50)	1	1.02 (0.11–1.49)	3	0.48 (0.15–1.49)	0.57 (0.18–1.83)	7	1.46 (0.53–3.98) [c†]	8	1.09 (0.41–2.91)[d*]
Knee	7	0.72 (0.32–1.58)	27	0.76 (0.47–1.21)	0.74 (0.50–1.10)	4	4.06 (1.02–16.24) [a*]	4	0.64 (0.24–1.71)	1.36 (0.58–3.21)	7	1.70 (0.64–4.50)[g*]	2	0.27 (0.06–1.25)
Ankle	8	0.83 (0.41–1.71)	23	0.63 (0.40–0.10)	0.67 (0.46–0.99)	2	2.03 (0.37–11.09)	4	0.64 (0.24–1.71)	0.90 (0.35–2.27)	0		2	0.26 (0.06–1.17)
Thigh	12	1.24 (0.67–2.28) [a*]	17	0.45 (0.26–0.77)	0.63 (0.43–0.94)	2	2.03 (0.43–9.56)	8	1.28 (0.64–2.56)	1.53 (0.70–3.37)[b*,f*]	2	0.37 (0.08–1.67)	2	0.26 (0.06–1.17)

[§] Reference group: In-season for season period comparison and Senior squad for age comparison. CI, confidence interval.

[*], P<0.05; [†], P<0.01; [‡], P<0.001; [a], difference in season periods; [b], Senior versus U21; [c], Senior versus U16; [d], Senior versus U14; [e], U21 versus U16; [f], U21 versus U14; [g], U16 versus U14.

Severity and Injury Burden

Table 3 Injury burden including upper and lower 95% confidence intervals (CI) in all squads with exposure records (*n* = 305 participants).

	Senior squad[§]					U21 squad					U16 squad		U14 squad	
n (% cohort)	188 (62)					53 (17)					33 (11)		31 (10)	
Exposure (hours)														
Total	49,247					7,228					5,600		7,813	
Pre-season	10,117					985								
In-season	39,130					6,243								
Season period	**Pre-season**		**In-season[§]**		**Entire season**	**Pre-season**		**In-season**		**Entire season**	**Entire season**		**Entire season**	
Injury category	**Severity**	**Burden (95% CI)**	**Severity**	**Burden (95% CI)**	**Overall burden (95% CI)**	**Severity**	**Burden (95% CI)**	**Severity**	**Burden (95% CI)**	**Overall burden (95% CI)**	**Severity**	**Burden (95% CI)**	**Severity**	**Burden (95% CI)**
Overall	1,087	217 (83–566)	3,766	253 (155–439)	235 (158–349)	1,047	10,187 (1,858–55,843)	2,017	4,590 (1,364–15,435)	2,695(1,162–6,254)[b‡, f‡]	1,712	1,314(332–5,199)[c*, g*]	802	259 (64–1,040)
Muscle	259	48 (12–189)	753	30 (14–66)	39 (22–68)	37	655 (166–2,585)	362	578 (329–1,014)	54 (16–181)[f*]	84	19 (3–135)	77	12 (2–86)
Ligament/tendon	175	31 (6–149)	839	23 (9–56)	27 (14–53)	761	24,509 (1,218–493,158)	1,127	3,970(299–52,776)	1,779(437–7,237)[b‡, f‡]	1,196	892 (90–8,798)[c‡, g‡]	90	20 (2–203)
Bone	77	10 (0.53–197)	563	19 (3–105)	15 (6–40)	89	3,031 (818–11,228)	217	1,061 (550–2,048)	49 (6–396)	387	146 (5–4,396)	394	114 (4–3,565)
Knee	156	20 (2–180)	1,613	131 (37–466)[a*]	75 (30–191)	834	39,005 (2447–621,766)	1,062	7,993 (1,019–62,706)	1,792(248–12,969)[b†, f†]	1,029	838 (33–21,317)	213	80 (3–2,110)
Ankle	299	111 (12–994)	615	29 (8–103)	70 (28–177)	83	1,508 (253–8,973)	154	1,090 (388–3,060)	61(8–445) [e‡]	0		148	25 (1–666)
Thigh	158	21 (3–159)	351	14 (4–45)	18 (8–39)	37	337 (37–3,117)	263	687 (203–2,328)	64 (12–345)[e*, f†]	40	9 (1–136)	27	3 (0.21–57)

[§] Reference group: In-season for season period comparison and Senior squad for age comparison. CI, confidence interval. [*], P<0.05; [†], P<0.01; [‡], P<0.001; [a], difference in season periods; [b], Senior versus U21; [c], Senior versus U16; [d], Senior versus U14; [e], U21 versus U16; [f], U21 versus U14; [g], U16 versus U14.

Injury Severity

The overall number of days lost was 23,067, with pre- and in-season of the U21s and senior players in addition to the U14s and U16s. Pre-season demonstrated 6,540 days absence (U21s with 2,133 days lost and the senior players with 4,407 days lost) and 13,514 days' absence in-season (U21s = 5940 days lost and senior players = 7573 days lost). The range for days of absence per player injury was 1-1289 days. The majority of pre-season injuries were non-contact (61.3%), with a moderate number of injuries of an unknown mechanism (36.0%) with contact injuries minimal (2.7%). Within pre-season most injuries occurred during training (74.6%) versus matches (25.3%) and resulting from overuse versus traumatic (41.3% vs 25.3%) with a third recorded as unknown (33.3%). Most in-season injuries were non-contact (41.4%) whereby many injuries had no mechanism detail recorded (43.1%) leaving contact injuries with a low representation (12.8%). In-season injuries appear to occur equally in matches and training within U21s and senior players (both 45.0%) with a minority during unknown activity (10.0%).

During pre-season, moderate injury severity (8-28 days) was the most represented severity category in the SNR squads (49.3%), while the majority of the U21s' injuries were in the >180 days category (n=5; 50%).

During in-season, the 'severe' injury category (29-90 days) was more highly represented in the senior squads (36.0%) followed by 8-28 days (33.7%) and >180 days (10.1%). The U21s also had the majority of injuries resolved within 29-90 days (41.2%), followed by 8-28 days (25.5%) with >180 days (13.7%) third most commonly reported category. The combined season phases for the U16s' most commonly reported category was 8-28 days (37.2%) with 29-90 days the second most reported in this age group (27.9%). The U14s age group had the highest category for 29-90 days (39.0%), followed by 8-28 days (29.3%) and >180 days (17.1%) as third most common.

Injury Location and Type

In pre-season, the most common injury location for the U21s was the knee (40.0%) and the SNR Squads was the thigh (41.8%). The most common injury location in-season for the U21s demonstrated thigh, knee and ankle locations to have the same percentage of injuries (19.6%). The senior players demonstrated a more varied injury in-season profile of the knee (25.6%), the ankle (19.4%) and thigh (18.1%).

The figure below highlights the percentage of injury locations with all squads demonstrating lower limb injury prevalence dominant. The U14s' most common injury locations were thigh (25.0%), knee and ankle (both 16.7%). The U16s' most commonly injured locations were the knee (23.3%), thigh and lumbar spine (both 20.9%). The U21s most commonly injured locations when the pre- and in-season were combined were the knee (24.2%), the thigh and ankle (both 16.7%). The senior players demonstrated the thigh (41.8%) as the leading injury followed by the knee (20.9%) and the ankle (11.9%).

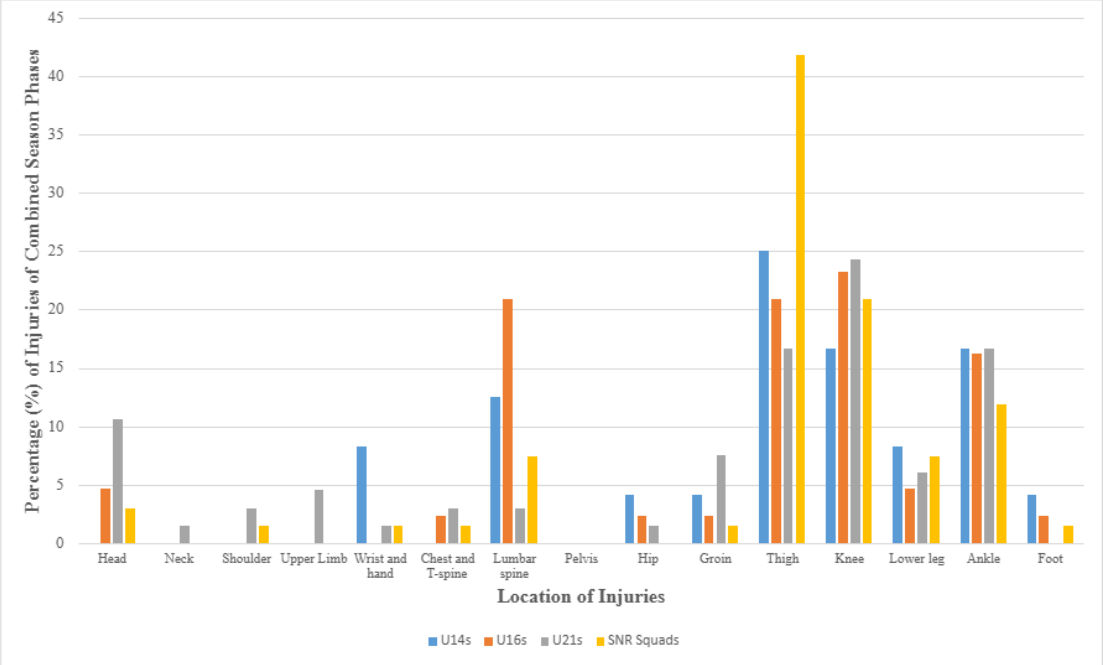

Figure 1 Displaying the Distribution of Injury Locations When Season Phases Combined (%)

Muscle Injuries

Of muscular injuries, 22.1% occurred in pre-season and 77.9% occurred during in-season (U21s and SNR Squads only). Figure 2 below displays the percentage of distribution of muscular injuries recorded for combined season phases for all squads. There were 122 muscle injuries pre- and in-season resulting in a combined total of 2,500 days lost. Of these, 27 injuries occurred in pre-season, which resulted in 377 days' (U21s = 3 days lost vs senior players = 374 days lost to muscular injuries) absence in pre-season compared to 95 muscle injuries in-season with a total of 2,126 days' (U21s resulting in 520 days' lost vs senior players 1606 days lost) absence. The median day loss in *pre*- and *in*-season was 15 and 17 days respectively. Injuries in this pre-season category occurred due to non-contact (70.4%), contact (14.8%) and unspecified events (14.8%). The majority of combined team pre-season muscular injuries occurred during training (59.3%) versus matches (29.6) with fewest with no activity specified (11.1%). When the pre-season injuries were split into the SNR and the U21s both teams demonstrated the majority of injuries in training, with all the U21s injuries occurring during training. In-season showed a similar pattern that the majority of muscular injuries occurred in training (41.1%) compared to matches (35.8%) with a smaller number of muscular injuries unspecified (23.2%). However, when the in-season muscular injuries were split by squads, the SNR squads remained to demonstrate a majority occurring during training versus matches (40.5% vs 31.7%) with some unspecified (27.9%) while the U21s demonstrated a higher occurrence of muscular injuries in matches versus training (56.3% vs. 43.8%). The majority of in-season muscular injuries were non-contact in nature (61.1%) with others unspecified (32.6%) and contact the lowest (6.3%). The majority of pre-season muscular injuries were reportedly caused through overuse (70.4%) followed by trauma (14.8%) with the same unspecified (14.8%). In-season demonstrated overuse injuries most frequently (34.7%) compared to unspecified (41.1%) and traumatic injuries (24.2%). Of SNR in-season muscular

injuries overuse and unspecified matched (38%) and traumatic injuries were least recorded (24.1%). Of the U21s in-season muscular injuries the majority were unspecified (56.3%) with traumatic second most commonly recorded (25.0%) with overuse as the least within U21s muscular injuries (18.0%). Most in-season muscular injuries resolved within 8-28 days (36.4%).

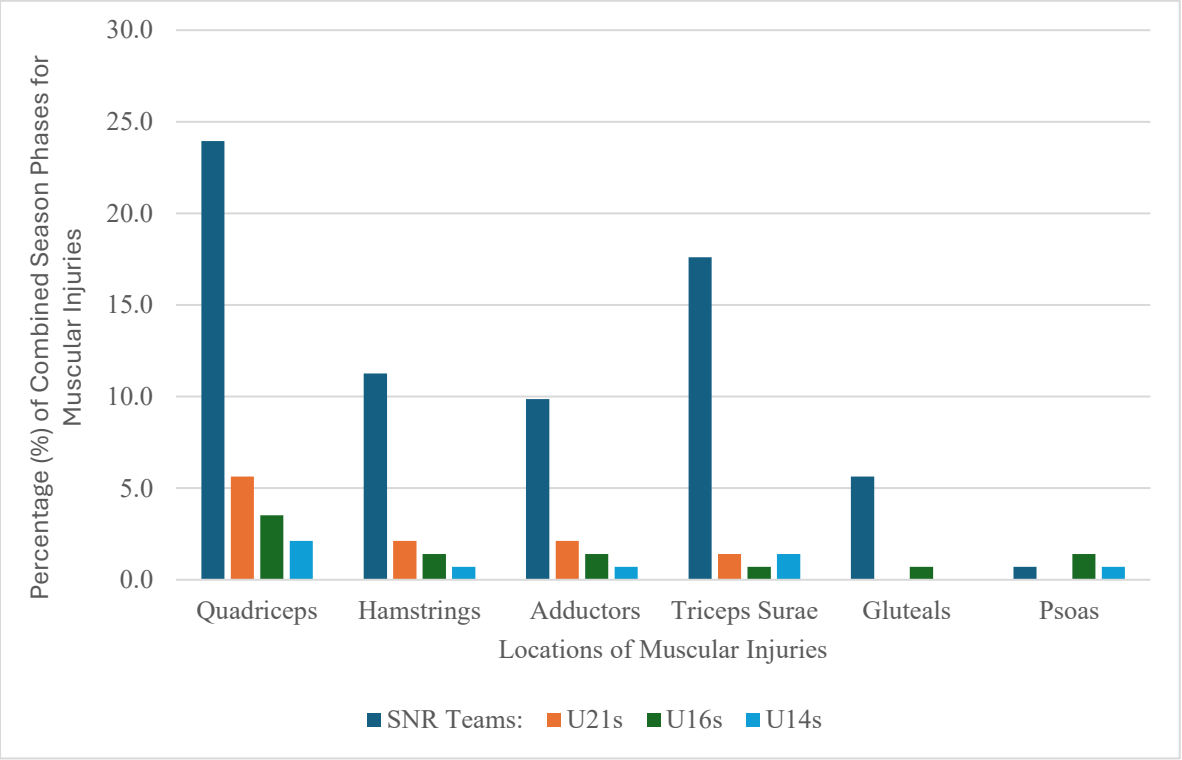

Figure 2 Displaying the Distribution of Muscular Injury Locations For Combined Season Phases (%)

Ligament Injuries

There were 110 ligament injuries with 11,075 days of absence in total for all squads. The U14s had seven ligament injuries resulting in 422 days absence and the U16s had 16 ligament injuries resulting in 1,217 days absence. Pre-season had reports of 16 ligamentous/ articular injuries resulting in 2,454 days absence compared to 71 ligament injuries in-season with a total of 6,581

days off and an average day loss of 36 days pre-season versus an average day loss of 26 days in-season. The majority of injuries in this category in pre-season occurred due to non-contact (75.0%), contact (12.5%) and unspecified (12.5%) occurring within most occurring during training (62.5%), less during matches (25.0%) with minimum having no known activity (112.5%). Traumatic (75.0%) injuries were the main cause of pre-season ligament injuries followed by overuse (12.5%) and unspecified (12.5%) ligament injuries. The majority of pre-season injuries resolved within 8-28 days (37.5%) and the knee ligaments were the most commonly injured pre-season (43.8%) followed by the ankle (43.8%). A similar pattern was demonstrated in that the majority of in-season ligamentous injuries were non-contact in nature (54.9%), with fewer contact (15.5%) and over a fifth unspecified (29.6%). Activities when injury occurred demonstrated that most occurred during matches (43.7%) versus training (36.6%) and a small number of injuries recorded with no specific activity reported (19.7%). Traumatic injuries were most commonly reported (62.0%), followed by unspecific (23.9%) and overuse reported least commonly (14.1%). The majority of in-season ligament injuries resolved within 8-28 days and 29-90 days (28.2%). The most common location of ligament injury in-season was the knee (47.9%) followed by the ankle (43.7%). The senior teams (44.4% of all ligament injuries), U-21s (50.0%) and U-16s (52.9%) reported the knee as most commonly injured ligament location however the U-14s had a higher frequency of ankle ligament injuries (50.0%) compared to knee ligament injuries (25.0%).

Observations of the SNR pre-season ligament injuries (of ligament injuries of the SNR squad) the ankle (8.3%) exceeded knee (6.9%) ligament injuries, followed by meniscus, cartilage, bursa (4.2%) and shoulder ligament injury (2.8%). In-season SNR squad ligament injuries demonstrated higher knee (37.5%) versus ankle (31.9%) ligament injuries followed by other (5.6%) and elbow (2.8%). The U21s pre-season ligament injuries (of ligament injuries of the U21s squad) knee ligaments were the only recorded ligament injury pre-season (12.5%)

and in-season ankle ligament injuries more common than knee ligament injuries (50.0% vs 37.5%).

Anterior cruciate ligament (Wahlquist et al., 2023b) with combination structural injury (meniscus) resulted in the highest absence (800 days, experienced by one individual player who had the highest number of days absent from a single injury) from soccer training and/or competition. There were 12 anterior cruciate ligament injuries: seven reported within the senior squads: one pre-season and the remaining six in-season, the English U-21s reported two ACL injuries in pre-season, and two more in-season with one further ACL injury reported for the U-16s team.

Lumbar Spine Injuries

There were 27 lumbar spine injuries overall causing 1,258 days absence. There were four lumbar spine injuries reported pre-season resulting in 151 days absence compared to 12 lumbar spine in-season with a total of 354 days off and an average day loss of 9.5 days pre-season versus 16 days lost in-season. The majority of injuries in this category in pre-season occurred due to non-contact (75.0%) with zero 'contact' injuries (0.0%) and some unspecified (25.0%). Further, pre-season lumbar spine injuries generally occurred during training environments (50.0%) with fewer during matches (25.0%) and some without activity identified (25.0%). The majority of pre-season lumbar spine injuries occurred due to overuse (50%) with fewer related to traumatic mechanisms (25%), with some unspecified (25%) and half of these injuries resolved within 4-7 days (50%). In-season showed a similar pattern in that most in-season lumbar spine injuries were non-contact in nature (75.0%) with no 'contact' incidents reported (0.0%) and some unspecified (25.0%). The majority of in-season injuries in this lumbar region occurred during training (41.7%) with a third during matches (33.3%) and others unspecified (25.0%).

The U14s demonstrated the highest severity of lumbar spine injuries with time to injury resolution (200 days) whereby all reported were non-contact, during training and overuse in nature. The U16s were also due to non-contact (100%) with half in training and half in match scenarios. The U16s demonstrated half were caused through traumatic events and half through overuse.

Senior versus Academy Aged Player Injuries

Table 2 displays the senior players and U21s pre-season IIR to be higher than that of in-season (4.51 [95% CI: 3.26-6.22] injuries/ 1000h) vs in-season (3.19 [95% CI: 2.56-3.99] injuries/ 1000h) and, U21s pre-season (16.58 [95% CI: 7.42-37.04] injuries/ 1000h) vs in-season (8.03 [95% CI: 3.88-16.62] injuries/ 1000h).

Regarding the between age-group analyses, both IIR and burden generally increased with advancing age for most injury types/locations but decreased in the senior players. The most frequently injured muscle pre-season was the quadriceps (66.7%), while the most frequent muscular injury in-season was the triceps surae (25.3%). Pre-season injuries were most frequent in the muscular category for senior players while for the U21s, ligament sprains were most frequent with the highest burden. Throughout in-season, muscular and ligament injuries were most frequent across all squads, with ligaments the most burdensome. Training activities were associated with the highest number of muscular injuries during both pre-season and in-season periods for the SNR squads. In contrast, while the U21s showed a similar trend in pre-season muscular injuries, they experienced a higher frequency of these injuries during matches rather than training sessions in-season, differing from the trend observed in the SNR squad.

U14s and U16s had a similar number of recruited participants (31 vs 33) with the younger squads accumulated exposure hours recorded as slightly more than the U16s (7,813 hours vs 5,600 hours). The overall IIR for the U14s was less than half of the U16s (U14s (2.98 [95% CI: 1.73-5.13] injuries/ 1000h) vs (6.62 [95% CI: 4.05-10.82] injuries/ 1000h).

The senior squads had a higher triceps surae than quadriceps IIR in-season. Of muscular injury pre-season, the three most commonly reported injured muscle groups were the quadriceps for senior players and U-21s (65.6%), gluteal muscle group (12.5%) with hamstrings and triceps surae (9.4%). The three most commonly reported muscular injury in-season for the senior players was the triceps surae (27.3%), followed by the quadriceps (26.4%) and adductors (18.2%). U21s and demonstrated a similar trend for quadriceps injuries for pre-season (100% and 40% respectively) (Refer to Figure 2 for combined season distribution of muscular injuries). Further to this, in-season muscle injuries demonstrated the quadriceps to be the highest rated injury across the U21s (46.7%) were the hamstrings (20%) and adductors (20%) matched.

Discussion

The primary aim of this study was to investigate the types, locations, IIR and burden of injuries occurring during pre- and in-season within female soccer players at professional clubs and academies in England and Spain. A second aim was to investigate injury patterns in different chronological age groups within women's soccer. We hypothesised that IIR and injury burden would be higher in pre- versus in-season, and that IIR and burden would increase with advancing chronological age (peaking in senior players). In line with our hypothesis, muscle and thigh IIR was higher in pre-season than in-season for the senior players, while knee and ligament/tendon IIR was higher in pre-season than in-season for the U21 players. Although IIR

and injury burden appeared to increase with advancing age (i.e. U21 > U16 > U14), contrary to our hypothesis, both IIR and burden were lower in the senior squads compared to U21 and U16, which may be due to greater sport science and medical support regarding injury prevention strategies for senior players.

The higher IIR during pre- than in-season for the senior and U21 squads may be attributed to the relatively long off-season in women's versus men's soccer (McQuilliam et al., 2022), which may have allowed the senior and U21 female players a period of deconditioning, reducing fitness levels. This combined with a sudden increase in load experienced by the players returning from the off-season without maintaining their training loads (Brumitt et al., 2018) may explain the higher IIR and burden we observed in pre- versus in-season within these squads.

The lower IIR in the senior and U21 squads in-season may be due in part to a protective effect of the loads experienced by players during the pre-season soccer period (Ekstrand *et al.*, 2020) and demonstrated in other sports (Windt *et al.,* 2016; Chandran *et al.*, 2021). As previously mentioned, conditioning can have an influence upon injury risk and severity whereby a sustained baseline level of fitness may reduce injury likelihood risk from overuse injuries in return to performance training and friendly matches (Colby *et al.*, 2017; Dalen-Lorentsen *et al.*, 2021). The importance of pre-season training has been demonstrated to allow for athlete performance longevity through reducing in-season non-contact related injuries while allowing for psychosocial preparedness for the competitive levels they are returning to (Ekstrand *et al.*, 2020; Waldén *et al.*, 2005).

The differences in IIR between U14, U16, U21 and the senior squads (Table 2), shows that it was lower in U14 compared to U16 and U21 for numerous injury types/locations. Due to mature players being more competitive and physical in their training and matches may predispose older players to increased injury incidence increasing with advancing age (Beech et al., 2022). Match play is also considered to increase injury risk by almost four times (Hallén et al., 2024). Considering this, our SNR squads demonstrated higher training versus match injury occurrence as did the U21s pre-season however, the U21s in-season match injuries exceeded training injuries potentially due to the heightened competitive nature and the opportunity to impress scouts and succeed in advancing into professional tier football at this important transition of a player's career. The U21s also demonstrated overall injury burden to exceed that of the other squads (Table 3), supporting previous evidence suggesting older elite male adolescent players (a prospective cohort study conducted in a male Dutch cohort over two competitive seasons, 15-18 years olds (Brink et al., 2012); vs 9-16 year olds vs 17-19 year olds (a prospective epidemiological study of 38 English youth academy clubs over two seasons (Price et al., 2004)) advancing towards professional league levels of play are more susceptible to sustain severe injury.

The U21 players had the highest pre-season and in-season injury burden (Table 3). This may be attributed to the competitive nature of matches and increased workload with reduced recovery time between sessions with the transition from academy to senior academy environments (Alentorn-Geli et al., 2009; Hall et al., 2022a). To note, the competitive nature to transition into a professional contract from the U21s with the potential sponsorship opportunities and career advancement may be a key driver for this. Potentially, pre-season recovery may not be as reinforced as with the senior quad players that may increase the prolonged post-exercise induced muscular biological products (creatine kinase and blood

lactate) to remain within the players system as access to certain recovery methods are not always accessible for female teams (Emmonds *et al.* 2019). A dated systematic review and meta-analysis identified lower creatine kinase and blood lactate levels to be present in studies that demonstrated positive effects through active recovery and cold water immersion (Gu *et al.* 2012).

This particular transitional phase of the U21s to SNR squads often observes rapid changes in training loads, tactical exposures and match demands (Silva et al., 2016). Physiologically, many of the U21s players have not established a fully stabilised neuromuscular control following peak height velocity, and may retain immature movement patterns as demonstrated in a small mixed cohort study (16 female and 17 males) investigating pubertal developments on neuromuscular control (Quatman et al., 2006). Psychosocial factors including increased competition for senior selection, academic pressures, or reduced access to appropriate staff may amplify the injuries (Steffen, Pensgaard and Bahr, 2009; Burton et al., 2023). Structurally, the U21s may lack the same medical surveillance support of senior squads while facing elevated expectations to train and perform at adult levels, particularly during the pre-season phase (McQuilliam et al., 2022). When compared to their U21s male counterparts, the U21s see a rise in injury incidence however, the magnitude does not match that of the female U21s with a Spanish cohort comparing male to female injuries with females having 21% increase in time lost (Larruskain et al., 2018). This potentially highlights sex-based differences in strength, tendon stiffness or landing mechanics, as well as the broader availability of tailored strength and conditioning within elite male cohorts.

The senior players demonstrated heightened in-season injury burden which contrasts with the U21s which could be attributed to congested training and playing schedules. An

explanation for the U16s age group injury overuse records may be due to the multi-sport exposure of players at school age who are required to take part in multiple sports for GCSE requirements and must perform well alongside their elite soccer training. Watson and Haroldstottir (2024) failed to demonstrate an association of increased injury within in-season injury or illness within elite female soccer players therefore, school sport may predispose more players to overtraining and injury through poorly managed performance-loading. In saying that, muscle injuries had the highest burden within the senior players, while ligament/tendon injuries had the highest burden within the U16 players. These findings were reflected in a recent study of overuse and overtraining whereby apophysitis type (e.g. injuries located at the calcaneus - Sever's disease or tibial tuberosity – Osgood Schlatter's Disease) and tendon injuries (especially patellar tendon) are reportedly more common in adolescent athletes (Brenner *et al*. 2024).

Furthermore, a concerning trend of 30-40% of injuries across in-season injuries regardless of age category appear to be within the severe burden category which suggests a systemic vulnerability across these categories showcasing the U21s as most at risk. When compared to male cohorts, males generally demonstrated higher injury incidence again, caution should be used when interpreting this as these studies were conducted within male professional Champions League teams and the UEFA injury study (Waldén, Hägglund and Ekstrand, 2005b; Ekstrand, Hägglund and Waldén, 2011). Albeit, a Spanish female cohort compared within its own male and female teams demonstrated females to have longer return to sport timelines resulting in higher severe injury profiles due to severe knee or ankle ligaments compared to their male counterparts (Larruskain et al., 2018) likely due to a combination of physiological differences in recovery, psychosocial factors and inconsistencies in post-injury rehabilitation (Chaudhari et al., 2007; De Ste Croix et al., 2017). This discrepancy raises critical questions as to why these differences exist and

evidence bases suggest biomechanical differences (hamstring to quadriceps ratios), neuromuscular control, hormonal influences, maturation, anthropometrics (same size pitch, females generally smaller than males), equipment (footwear based upon male foot shape), an evidence base using male cohorts as the gold standard although obvious physiological differences exist, potential disparities in resources and medical and conditioning staff/ resources (Free Communications, Poster Presentations: Tissue Mechanisms, 2005; Ericksen and Gribble, 2012; Emmonds, Heyward and Jones, 2019b; Arundale et al., 2020; Andrade et al., 2021). The high burden of severe injuries appears not to be isolated to female players but may be exacerbated in female squads due to the structural and support related inequalities. These findings underscore the urgent need for age and sex-specific injury surveillance, tailored rehabilitation plans and enhanced access to support pathways.

Muscular injuries may be due to the return to loading and overloading that the tissue fibres require more recovery (Hughes *et al.*, 2018), adaptable conditioning strategies (Colby *et al.*, 2017) and nutritional support for holistic athlete management (Hausswirth *et al.*, 2011). A number of studies have investigated the prolonged recovery of older athletes and linked this to metabolic resistance which may be due to extracellular stiffening alongside unresolved inflammation, caution interpretating the findings of Li et al. (2024) as their population studied was of advanced age. The Li et al. (2024) article is a narrative review that focuses upon the nuances of altered recovery to resistance induced muscle damage (EIM in older adults. The study emphasized that the response in aged muscle tissue displays prolonged, delayed and inefficient recovery due to factors such as anabolic resistance, extracellular matrix stiffening, mitochondrial dysfunction, unresolved inflammation and altered satellite cell repair. The Li et al (2024) review populations are older than the population of this current study and younger adult recovery from exercise induced muscle damage are typically

considered efficient. Therefore, the age-related alterations demonstrated in older populations are less likely to influence the recovery in younger cohorts.

Subsequently, the impairments of prolonged recovery appear to impact the overall time loss for older athletes which may explain the heightened burden of injury within the senior squads and U21s. Of note, there are complex training variables that occur dependent upon the type of training variables intensity, volume and frequency, and the exposure length i.e. acute and chronic load exposure which have variable impact upon muscle, ligament, tendon, bone and joint injuries of players (Gabbett and Oetter, 2025).

Pre-season should be included in the overall season periodization (training specificity, intensity and volume) planning to promote long term, full-season performance improvements (Beato et al., 2021). Ligament injury burden was highest for the U21s squads in-season, and highest overall burden across all squads. Due to the reduced oxygen supply ligaments receive in comparison to tendon and muscles contributes to longer healing and recovery from injury (Leong et al., 2020). Growth injuries were more prominent for the U14 and U16 squads compared to U21s and senior squads most likely due to players in the U21s and senior squads being biologically mature (Albaladejo-Saura et al., 2022).

Pre-season injury reports demonstrated that the lower limb was the most injured with thigh, knee and ankle locations most prominent. Pre-season demonstrated that most muscle injuries were from overuse and more common than articular injuries, with the quadriceps muscle reported as the most commonly injured muscle group for the senior squads and U21s with the overall U16s muscle injury location which is in agreement with previous studies (Larruskain *et al.*, 2018). There was a variation of most commonly injured muscle groups in-season, showing the senior squads had a higher occurrence in the triceps surae. No other injury

audit in women's soccer has demonstrated the triceps surae as the most injured muscular group. However, the most commonly injured muscle group within the in-season U21s was the quadriceps agreeing with previous literature in a Spanish cohort (Larruskain *et al.*, 2018). This may be due to several factors, such as increased scheduled training and more friendly matches without an adequate pre-season. Also, this may be due to exposure to other sports that younger athletes may participate in, which may augment strength and fitness, potentially protecting against injury (Dalen-Lorentsen *et al.*, 2021; Mandorino *et al.*, 2023).

The senior squads' and U16s' most common injury location was the knee, which is in accordance with findings from a season-long Brazilian elite soccer cohort (Gasparin et al., 2024), while the U21s was the thigh in agreement with previous findings in a Spanish cohort (Larruskain et al., 2018), and the U14s' most common injury location was the ankle ligament, which is in line with previous findings in female academy players (Le Gall, Carling and Reilly, 2008; Beech et al., 2022). The highest injury burden in all squads was due to ACL injuries, which agrees with a recent prospective injury study by Hallen *et al*. (2023). The senior squads included in our study had the highest number of ACL injuries (n=7), one in pre-season and six in-season. The U21s had two ACL injuries during pre-season and two in-season, with the U16s having one reported. Due to the time-loss and sequalae of ACL injuries, there is a heightened need to further investigate the importance of all-season injury prevention strategies (Hallen *et al.,* 2023).

Of the 12 ACL-injuries identified during the present study, the majority occurred during in-season (pre-season: n=3, in-season=9) and generally within senior squads. An explanation may be due to the potential of deconditioning during the off-season and returning to a peak in training on return to pre-season training with an increase in training load, volume and

competitive match demands in-season (Crossley et al., 2020). The increased training and competitive accumulated load exposure during in-season appears to have a protective effect on the burden of ACL injuries, as pre-season ACL injuries have a greater burden in comparison, which is a modifiable risk factor (Bradsell and Frank, 2022). Table 3 presents a high injury burden, with the calculation of burden including median number of days, if there is an outlier, which ACL injuries contribute to high outlying totals of days lost, inflates the overall burden for ligament injuries, so take caution. Also, of note, ACL injuries have been sensationalized with literature proclaiming an 'epidemic'. Recent literature has addressed that the injury has remained around 2-3.5 times increased risk in females versus males in elite (Waldén et al., 2011) and within ball sports (Chia et al., 2022). A systematic review and meta-analysis in 14 sports with adolescent male and female youth athletes (12-19 years old) investigated ACL injuries identifying 26 eligible studies. Altogether 1,235 ACL-injuries had been recorded with 13 studies soccer-specific and showing female soccer players to have a 1.21% risk per season for an ACL injury in comparison to male soccer players 0.39% (Bram et al., 2021). Further to this another systematic review reported ACL IIR to be 2.2 times higher risk in females compared to males when exposure was per 1000-h (Montalvo et al., 2019).

There is a need to increase recruitment from the younger academy groups, i.e. U16s, U14s and U12s, to investigate growth-related injury patterns in players progressing through maturation, and relative age effects on incidence, burden, location and tissue type. Further to this, in the academy systems, efforts to record activity while in attendance, hours dedicated to match, training or rehabilitation would support injury researchers. The academy players of school age are also required to take part in school-related physical activity and/ or matches that increases cumulative exposures to training and competitions increasing player loads. These activities are not recorded via the club and a player may potentially become injured or be

subject to fatigue without the club being notified. This study was limited to club football in England and Spain and, although these squads have players of mixed nationalities, our results are not necessarily generalizable to all female academy and senior players.

The variation of injury types by season phase demonstrated soft tissue overload type of syndromes in pre-season for the SNR squads muscular injuries and the knee ligament tissue as the most frequently injured in pre-season in the U21s most likely reflecting the abrupt increase in training loading, insufficient neuromuscular preparation and poor periodization. In contrast, in-season demonstrated both the SNR and U21s to have frequent muscular and ligament injuries which saw an increase in ligament injuries that tend to be more severe with longer return to sport timelines (SNR squads most frequently injured muscle group being the triceps surae and the U21s the quadriceps). The most frequently injured ligaments in-season were the knee ligaments (SNR squads=48.2% and U21s=53.3% of ligament injuries). These seasonal trends should inform the practitioners needs to align prevention strategies with phase-specific risks: structured load management and eccentric strength development should be prioritised in pre-season, while in-season strategies should focus on fatigue monitoring, recovery protocols, and neuromuscular control under competitive, match-like conditions as two systematic reviews demonstrate the importance within youth and adult athletes (McCall et al., 2015; Mandorino et al., 2023).

Unexpected findings include the hypothesis that SNR squads would exceed IIRs of the younger age groups was rejected due to the U21s squads exceeding IIRs beyond the SNR squads. When comparing the SNR to the U21s squads pre-season IIR, the U21s is four-times that of the SNR squads (U21s: IIR 16.58; 95% CI: 7.42-37.04 versus SNR: IIR 4.51; 95% CI:

3.26-6.22) and the in-season was not of the same magnitude although remained double in the U21s versus the SNR squads (U21s: IIR 8.03; 95% CI: 3.88-16.22 versus SNR: IIR 3.19; 95% CI: 2.56-3.99). When the season phases were combined the U21s demonstrated a significantly higher IIR than the SNR squads ($p<0.05$). In addition, when burden was analysed, the SNR squads demonstrated a higher in-season injury burden versus pre-season in contrast to the U21s whose pre-season burden exceeded that of the in-season as hypothesised. The SNR squads demonstrated a lower pre-season burden versus the U21s squads and this trend continued into the in-season. When comparing the combined season phases burden, the U21s showed great significance ($p<0.0001$). Additionally, the locations of injuries were in contrast to previous findings. The SNR squads had the highest frequency of pre-season injuries within the quadriceps and in-season in the triceps surae in contrast to the Hallen et al. (2024) UEFA Injury study that demonstrated most frequent injured muscle group was the hamstrings. Partial agreement in SNR squads in-season of the full-season study conducted in a Spanish female cohort by Larruskain et al. (2018) demonstrated quadriceps as the most frequent, agreeable to our SNR squad findings.

Caution is warranted in the interpretation of results as these are reflective of the clubs studied in this gender-specific and club-specific contexts at this playing level. It should be acknowledged that for every age category variability exists across the coaching and medical team provisions, as well as access to facilities and the variation of time of day training/ matches occur alongside the differences in coaching styles, talent selection, the actual facilities/ recovery resources, and athlete injury/ experience history may limit the external validity (Arora et al., 2023). The missing data (unknown mechanisms, is an unfortunate common theme in sports literature) can introduce risk of bias and reduce statistical power,

lower confidence in interpretations, heightening the chances of false positives and limit the replicability (Mesquida et al., 2022; Owen et al., 2022). This injects important nuance around representativeness, missing data and bias.

This study is not without its limitations. Unfortunately, it was not possible to split the exposure data between pre- and in-season for the U14 and U16 squad groups, so the pre- vs. in-season IIR and burden analyses were limited to the senior and U21 squad groups. Albeit, the sample size that exposure data was available to allow analyses was ~80% which adds strength to the analyses. The limited sample size of the U21s group likely influenced the statistical model regarding the pre- vs in-season injury burden analyses, so caution should be applied when considering these results. Presentations and information sharing were hosted with participating staff members at the clubs and with players to familiarise them with the excel records sheets and information that was being sought. Not all details of injuries were recorded by the club staff as shown within the injury audit and this is acknowledged as 'unspecified'.

Conclusion

Muscle and thigh IIR were statistically higher in pre-season than in-season for the senior squads, while knee and ligament/tendon IIR were statistically higher in pre-season than in-season for the U21 squads. The quadriceps muscle group was demonstrated as a frequent injury across all squads featuring in the top three of muscle injuries alongside the SNR team demonstrating triceps surae as a key muscle group to target in injury prevention and performance enhancement. Although IIR and injury burden appeared to increase with advancing age (i.e. U21 > U16 > U14), both IIR and burden were lower in the senior squads compared to U21 and U16, which may be due to greater sport science and medical support regarding injury prevention strategies for senior players compared to academy squads. Thus,

injury prevention strategies in senior and U21 women's soccer should focus on reducing injury risk in the pre-season period. Furthermore, greater attention should be placed on injury prevention in the U16 and U21 squads, while future research should investigate the reasons for seasonal- and age group-specific associations with injury risk in women's soccer.

Practical Applications:

Implement and disseminate findings by utilising the ACE-STAR Knowledge Transformation Model and transform findings into guidelines, training modules or checklists in ready to apply formats for coaches and medical teams (Manspeaker, 2010). Involve stakeholders at all levels to in order to increase awareness and deliver statutory evidence based professional development for governing body requirements. Best practice would be to pilot, evaluate and iterate in several clubs if possible and monitor the effectiveness through standardised protocols. Targeted injury prevention per-season phase, gender-specific and age-specific. Through using mixed methods to assess adherence, barriers and outcomes to refine any issues prior to scaling nationally. Through improving access to simple platforms to build monitoring and feedback responses and using consensus recommended tools for tracking loading, recovery, stress, readiness and menstrual cycles would assist in coaches visualizing progress and adaptations of protocols (Kellmann et al., 2018). Once pilot studies have been carried out, collaborate with national bodies regarding the findings of interventions and scale recommendations through coach education frameworks, accreditation standards and performance pathways at different levels (Schaillée et al., 2019).

Tailor interventions in pre- and in-season for female soccer players with precision in order to reduce injury risk while optimizing performance. Considering the demographics included ensure that the interventions are not only sport-specific but age-specific through

adopting a flexible framework that allows for athlete tissue real-time adjustment considerate of players in varying phases of peak height velocity or adult status. Athlete feedback and data analysis of biomechanical considerations can markedly improve both the preventive and performance initiatives. Recognising how the season phases can assist in athlete performance and injury management are pivotal to create sustainable progress.

Interventions include and are not limited to:

- Female athlete and age-specific pre- and in-season performance plans
- Meticulously planned periodization, considering the complexities of the acute versus chronic tissue adaptation applying the understanding of this to the pre- and in-season training plans
- Integrate learning from continual professional development effectively, ensuring it is not only meeting tick box requirements from professional statutory bodies but contributes to meaningful practice
- Effective monitoring of players development
- Suitable platform to document and record guideline directed data regarding player exposures, injury recording and reporting and ensure robust data protection measures adhered to
- Contextual factors such as season timing, team level, age, gender, individual athlete schedule (congested with European or International fixtures or light no selection for European or International fixtures)
- Source suitable recovery methods and if not available with club education on benefits and how to access these if not accessible.
- Off-season programmes with access to facilities and professional staff
- Maintain effective and comprehensive athlete management through a holistic dedicated support team throughout all season-phases.

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