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Injury, illness, and mental health problems during the 2023 FIFA Women's World Cup

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ABSTRACT

Our study aimed to describe the patterns and characteristics of injuries and illnesses incurred during the FIFA Women's World Cup 2023 (FWWC2023). Team medical personnel recorded all injuries, illnesses, and mental health problems requiring medical attention, plus match, and training exposure into a centralised FIFA database using recent consensus-based methodology. Of the 32 teams at FWWC2023, 26 teams participated in the study, including 536 of 742 players. A total of 161 medical-attention injuries (incidence rate (IR): 14.2 per 1000 h [95% CI: 12.1 to 16.6]) and 59 time-loss injuries (IR: 5.2 per 1000 h [CI: 4.0 to 6.7]) were reported. Time-loss match injury IR was 14.0 per 1000 h [CI: 8.9 to 21.1] and training IR 2.2 per 1000 h [CI: 1.3 to 3.3]. The knee and thigh were the most frequently injured locations, while the lower leg created the highest overall time-loss burden. Time-loss injuries were mostly reported from contact mechanisms (59%), particularly with an opponent. There were 41 medical-attention illnesses (IR: 4.2 per 1000 player-days [CI: 3 to 5.6]) and 8 time-loss illnesses (IR: 0.8 per 1000 player-days [CI: 0.3 to 1.6]) reported. Respiratory illnesses (16 medical-attention and 7 time-loss) were the most frequent, with a burden of 1.2 days lost per 1000 player days [CI: 0.4 to 2.2]. The IR of mental health problems was low (0.2 per 1000 player-days [CI: 0.02 to 0.7]). Compared to previous international tournaments of both sexes, injury incidence and burden at the FWWC2023 was low.

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KEYWORDS
Epidemiology; female; football; soccer; prevention

Background

Time-loss injuries are known to have negative consequences for player health and team performance in professional football (Hagglund et al. 2013; Eirale et al. 2013). Recent injury reports from women's football clubs playing in the premier domestic leagues of Europe, Australia, and Africa give insight into the injury patterns in women's professional football (Olanrewaju et al. 2019; Hallén et al. 2024; Leonard et al. 2024). However, the last published report of injuries from international competition at FIFA Women's World Cup was in 2011 (Junge and Dvorak 2013). Substantial changes to the women's game have occurred since then, with a greater proportion of professional women football players engaged in full-time training and competition. Furthermore, despite the impact and risk of transmission (Bjørneboe et al. 2016), illness rates have not previously been reported from a FIFA Women's World Cup. It is well established that injury and illness surveillance is essential for informing the development and the evaluation of prevention strategies (van Mechelen et al. 1992; Finch 2006). To continue the development of effective preventative strategies, an updated report of the epidemiology of injuries and illnesses reported at the top-level of women's football is required.

In 2020, the International Olympic Committee (IOC) released a consensus statement on recommended methods for recording and reporting sport-related injury and illness epidemiological data (Bahr et al. 2020), with a football-specific extension of this statement published in 2023 (Waldén et al. 2023). Consistency with the recording and reporting procedures agreed upon in these

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consensus statements allows for the comparison of injury and illness burden across populations (Waldén et al. 2023), facilitating the development of population-specific prevention strategies. The importance of considering and reporting the impact of mental health problems on player health and performance has also been highlighted in two recent IOC consensus statements (Reardon et al. 2019; Mountjoy et al. 2023). However, mental health problems have not previously been reported in women's football at international competition level.

Therefore, the aim of our study was to report the pattern and characteristics of injuries, illnesses, and mental health problems sustained by footballers participating in the FIFA Women's World Cup Australia and New Zealand 2023™ (FWWC2023).

Methods

Our prospective cohort study was approved by the Swiss Association of Research Ethics (BASEC-ID: 2023–00772) and La Trobe University Human Research Ethics Committees (2023–00772). All included players provided written informed consent for the use of their data for research purposes, and data were handled in accordance with European data protection regulations (GDPR). The FWWC2023 tournament was played in various locations throughout Australia and New Zealand between 20 July and 20 August 2023, with a total of 64 matches played over 32 days.

Study duration

The surveillance period was from 15 July to the 20 August 2023. Each team recorded all new injuries, illnesses, and mental health problems that occurred among their players, starting from 5 days prior to their first match until the day of their last match of the tournament. Cases which occurred prior to the observation period were excluded from the analysis. All cases were followed until the player's full return to team training, even if this occurred post-tournament.

Participants

All participants in this study were football players selected on the final team lists for the FWWC2023. The FWWC2023 included 32 national teams, with each team allowed to select up to 23 players. As teams could replace sick or injured players until 24 h prior to the commencement of their first match, a total of 742 players were registered for FWWC2023 and eligible for inclusion. Each player was invited to participate through their team medical staff. A translator was provided if language was a barrier to providing study information. All participating football players who provided informed consent were included, and there were no exclusion criteria.

Injury and illness registration

A local team of surveillance officers divided the responsibility of supporting teams to perform the surveillance, each responsible for 2–6 teams. All registered teams were provided with written informed consent forms, study information manuals, and registration forms in English, French, and Spanish (Appendix 1). Other language requirements were aided by a bi-/multi-lingual surveillance officer, team translator, or an artificial intelligence translator tool (DeepL SE, Cologne, Germany). Teams were informed of the study 3 months, 1 month, and 1 week prior to the observation period. Each participating team of this study nominated a member of their medical staff to report de-identified injury, illness, and exposure data for their team via an online platform (Appendix 2).

Data were recorded according to the recommendations of the football-specific and mental health extensions of the IOC consensus statement on methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (Bahr et al. 2020; Waldén et al. 2023; Mountjoy et al. 2023). Injury was defined as tissue damage or other derangement of normal physical function resulting from rapid or repetitive transfer of kinetic energy (Waldén et al. 2023). Illness was defined as a health-related complaint or disorder experienced by an athlete, not considered an injury or mental health problem (Bahr et al. 2020). Mental health problems were defined as any adverse thoughts, feelings, behaviours, and/or psychosomatic symptoms that reduced a player's normal state of full mental health (Mountjoy et al. 2023). Teams representatives were instructed to report all cases that required medical attention, irrespective of whether they led to time-loss from training and/or matches. Time-loss was defined by a player being unable to complete full training or competition due to their health problem.

Injuries were categorised according to body area, tissue type, pathology type, mode of onset, mechanism, player action, and referee sanction (Waldén et al. 2023). Illnesses were categorised according to organ system and aetiology (Waldén et al. 2023), and mental health problems were categorised according to symptom clusters (Mountjoy et al. 2023). All cases were classified as a new (first known presentation) or subsequent health

problem, with subsequent cases further classified as (1) reinjuries/repeated illnesses/repeated mental health problems, or (2) exacerbations, depending on whether the player had returned to unrestricted football participation since the initial episode (Bahr et al. 2020).

Injury, illness, and mental health problem severity was defined as the number of days lost from football training and match play (time-loss days). Time-loss was calculated from the date of health problem onset (i.e., day 0) until the date when the player returned to full unrestricted team training or match participation (partial or full) whichever occurred earliest (Waldén et al. 2023). When recording each case, team medical staff provided an initial estimate of severity, which was confirmed or updated through the reporting system when the actual time-loss was known. After the tournament, all unconfirmed cases were followed up by surveillance officers to obtain actual time-loss.

Diagnostic coding

Following data collection, all cases were coded by one member of the research team with extensive coding experience (BC) according to the Orchard Sports Injury and Illness Classification System, version 15 (OSIICS-15). All codes were reviewed by four other members of the research team with coding experience (AM, AS, DL, MW), with discrepancies resolved by consensus. Diagnostic codes were based on free-text descriptions of the diagnoses from team medical staff. Appropriate non-specific codes were used if information was insufficient for a specific diagnosis. We did not attempt to diagnose mental health problems, with all cases assigned a non-specific OSIICS-15 code, MSZX.

Exposure registration

Each player's football training exposure, and if played, individual match exposure was reported in minutes by their team representative. Individual match exposure was verified using match data collected by FIFA match analysts. In addition to on-pitch football-specific training, strength and conditioning, warm up and cool down activities were recorded as training exposure (Waldén et al. 2023).

Statistical methods

Incidence and burden rates were reported separately for all relevant combinations of (1) medical-attention injuries, illnesses, and mental health problems, (2) time-loss injuries, illnesses, and mental health problems, (3) gradual-onset and sudden-onset injuries, and (4) match and training injuries. Time-loss injury incidence rates, as well as median severity and interquartile range (IQR), were also reported for all body areas, and for subcategories of tissue, pathology, and diagnosis. Injury exacerbations and injuries unrelated to football activity, were excluded from all analyses.

Median time-loss was only reported for categories with more than one case, interquartile range (IQR) for time-loss days was only reported for subcategories containing five or more cases. Injury incidence rates (IR), median time-loss days, and burden rates were only reported for specific diagnoses when there were five or more cases of that diagnosis. Non-specific diagnoses were not included in tables.

For all injury outcomes, incidence and burden rates were expressed as the number of new injuries and number of time-loss days per 1000 h of exposure, respectively. As no injury events led to multiple injuries, the terms injury IR and injury event IR are synonymous. Following consensus recommendations, for Illnesses and mental health problems, incidence and burden rates were expressed per 1000 player days (Waldén et al. 2023). To enable comparisons between all types of health problems, incidence and burden rates of all medical attention and time-loss injuries were also presented per 1000 player days. R statistical software was used for all analyses (version 4.3.1). As we expect our incidence and burden rates to be compared to other similar datasets, the imprecision of our estimates was represented by 95% confidence intervals (CI). For IRs, we used the EpiR package to calculate 95% CIs using the exact method (Stevenson et al. 2024). For burden rates, we used the Boot package to calculate 95% CIs using bootstrapping with 10 000 draws (Mountjoy et al. 2023), sampling at the player level to account for the occurrences of multiple injuries in the same player. If a player's training exposure was missing (29 of 536 players), the missing value was imputed based on the player's match exposure, team, and playing position using the mice package with the predictive mean matching method (Buuren and Groothuis-Oudshoorn 2011). To ensure the validity of the imputed data, we compared the mean and distribution of the original and imputed datasets.

Sample size

All players participating in the FWWC2023 were invited to participate, therefore no *a priori* sample size calculation was necessary.

Results

Participants

A total of 536 players from 26 teams provided written informed consent to participate, representing 81% of all teams, 89% of players on participating teams, and 72% of all players at the FWWC2023. The median age, height, and body mass of the participating players of this study was 26y (IQR: 23–30, range: 17–40 y), 168 cm (IQR: 163–172, range: 140–187 cm) and 60 kg (IQR: 56–65, range: 40–78 kg), respectively.

In total, players had 11,349 h of football exposure (9,705 h of training and 1,644 h of match exposure), and 9884 days of total exposure within the observation period.

Injury characteristics

We recorded 161 medical-attention injuries among 102 players (19% of participating players of this study) at an overall IR of 14.2 per 1000 h [95% CI: 12.1 to 16.6], 16.3 per 1000 player days [CI: 13.9 to 19] (Appendix 3). The match injury IR for medical attention injuries was 31.0 per 1000 h [CI: 23.1 to 40.8] and training injury IR was 4.8 per 1000 h [CI: 3.6 to 6.4]. All 26 participating teams of this study reported at least one medical-attention injury, with a wide variation in the number of reported cases between teams (median: 4, IQR: 2–5, range: 1–58).

When the 161 medical attention injuries were grouped by severity, 102 injuries led to 0 days lost (63%), 25 led to 1–3 days (16%), 14 led to 4–7 days (9%), 16 led to 8–28 days (10%), 2 led to 29–90 days (1%), and 2 led to 91–180 days (1%) (Table 1). There were 92 medical-attention injuries recorded as new injuries, 14 as reinjuries, and in 55 cases it was unknown whether the player had previously had the same injury. Of these 55 cases with unknown history, 50 cases did not lead to any time-loss, and the remaining 5 cases led to less than 7 days.

A total of 59 time-loss injuries in 55 players (10% of participating players of this study) were reported at an overall IR of 5.2 per 1000 h [CI: 4.0 to 6.7], 6.0 per 1000 player days [CI: 4.5 to 7.7]). Injury distribution, incidence, and burden rates by body area and tissue/pathology type are presented in Tables 1 and 2. The time-loss injury match IR was 14.0 per 1000 h [CI: 8.9 to 21.0] and time-loss training injury IR was 2.2 per 1000 h [CI: 1.3 to 3.3]. Twenty-three teams (88%) reported at least one time-loss injury (median: 2, range 1–9). A total of 735 days of time-loss due to injury were recorded, resulting in an injury burden rate of 64.6 days lost per 1000 h [CI: 30.8 to 110.4] and 74.3 days lost per 1000 player days [CI: 35.2 to 127.9]. The most frequently injured body areas reported were the thigh, lower leg, knee, and head (Table 1 and Figure 2). Lower leg injuries caused the highest injury burden (22 days lost per 1,000 h), followed by injuries to the ankle (13 days lost per 1,000 h) (Figure 1). The most commonly injured tissue types were muscle and tendon (27 cases, 46%) and ligament (11 cases, 19%), followed by nervous system (7 cases of concussion, 12%) and cartilage (5 cases, 8%). Ligament and muscle and tendon injuries had the highest burden (23 and 18 days lost per 1,000 h, respectively) (Table 2).

Injury mechanisms and circumstances

Among the 161 medical-attention injuries, 97 (60%) occurred with sudden onset and 64 (40%) occurred with a gradual onset (IR: 8.7 per 1000 h [7.1 to 10.6] and 5.6 per 1000 h [4.3 to 7.2], respectively, Appendix 3). Of the 97 sudden-onset medical attention injuries, 51 (53%) occurred during a match and 46 occurred during training.

Most of the 97 sudden-onset medical attention injuries (74, 76%) were contact injuries (67 direct and 7 indirect contact) with 23 injuries classified as non-contact (24%). The contact was mainly from an opponent (46, 62%) but also occurred from a teammate (10, 14%), the ball (8, 11%), a pitch object (1, 1%), the goal post (3, 4%), or another object (6, 8%). The player action reported at the time of the sudden-onset medical attention injuries was: in a tackle (20 injuries, 27%), running (9, 12%), in a collision (8, 11%), heading (8, 11%), kicking (8, 11%), while changing direction (4, 5%), while controlling the ball (4, 5%), being hit by the ball (4, 5%), falling (4, 5%), landing (2, 3%), and unknown/other (3, 4%).

For the 59 time-loss injuries, 44 (75%) occurred with sudden onset and 15 (25%) occurred with a gradual onset (IR: 4.0 per 1000 h [2.9 to 5.3] and 1.3 per 1000 h [0.7 to 2.2], respectively).

Most of the 44 sudden-onset time-loss injuries (26, 59%) were contact injuries (22 direct and 4 indirect contact) with 18 injuries classified as non-contact (41%). The contact reported was with an opponent (17, 65%), a teammate (6, 2%), and the ball (3, 12%). In terms of injury circumstances for the sudden-onset time-loss injuries, 23 (52%) occurred during a match and 21 occurred during training. Injury burden is visually represented in risk matrices (Figure 1). Lower leg injuries had the highest burden for sudden onset injuries, and groin and knee injuries had equal burden for gradual onset injuries (Figure 1).

For sudden-onset time-loss injuries, the most common player actions at the time of injury were changing direction (8, 18%), running (7, 16%), in a tackle (5 injuries, 11%), heading (5, 11%), and kicking (5, 11%) (Figure 2).

Table 1. Pattern of time-loss injuries by body area, for the more common injuries by tissue type, pathology type, and/or diagnoses.

Body area Tissue Type Pathology *Diagnosis*	Injuries	Incidence rate		Median time loss		Burden rate	
	n (%)	New injuries/1000 h (95% CI)		Days (IQR*)		Days lost/1000 h (95% CI)	
Head	**9 (15%)**	**0.79**	**[0.36 to 1.5]**	**7**	**(4 to 8)**	**4.64**	**[3.06 to 6.22]**
Nervous system	7	0.61	[0.25 to 1.26]	7	(5.5 to 9)	4.22	[2.90 to 5.45]
Concussion	7	0.62	[0.25 to 1.27]	7	(5.5 to 9)	4.22	[2.90 to 5.36]
Neck	**2 (3%)**	**0.18**	**[0.02 to 0.63]**	**1.5**	**(1.25 to 1.75)**	**0.26**	**[0.18 to 0.35]**
Shoulder	**1 (2%)**	**0.09**	**[0 to 0.49]**				
Lumbosacral	**1 (2%)**	**0.09**	**[0 to 0.49]**				
Groin	**4 (7%)**	**0.35**	**[0.1 to 0.9]**	**9**	**(7 to 14.75)**	**4.47**	**[2.45 to 7.44]**
Thigh	**10**	**0.88**	**[0.42 to 1.62]**	**6.5**	**(2.75 to 8.5)**	**6.13**	**[3.50 to 9.46]**
Muscle/tendon	10	0.88	[0.42 to 1.61]	6.5	(2.75 to 8.5)	6.15	[3.52 to 9.40]
Muscle injury	8	0.7	[0.3 to 1.39]	6.5	(4.25 to 7.75)	5.19	[2.72 to 8.35]
Non-specific thigh muscle injury	3						
Semimembranosis strain	1						
Rectus femoris strain	2						
Adductor longus strain	2						
Muscle contusion	2	0.18	[0.02 to 0.63]				
Knee	**11 (19%)**	**0.97**	**[0.48 to 1.73]**	**4**	**(1.5 to 9)**	**10.94**	**[3.06 to 21.28]**
Muscle/tendon	2	0.18	[0.02 to 0.63]				
Bone	1	0.09	[0 to 0.49]				
Cartilage/synovium/bursa	4	0.35	[0.1 to 0.9]				
Joint cartilage injury (unspecified)	2						
Lateral meniscal tear	1						
Patellofemoral joint chondral pain	1						
Ligament/joint capsule	4	0.35	[0.1 to 0.9]				
Medial collateral ligament injury	2						
Posterolateral corner and lateral collateral ligament injuries	1						
Patellar subluxation	1						
Lower leg	**9 (15%)**	**0.79**	**[0.36 to 1.5]**	**7**	**(3 to 21)**	**21.98**	**[3.15 to 52.62]**
Muscle/tendon	8	0.7	[0.3 to 1.38]	5	(3 to 12.75)	6.24	[2.20 to 12.83]
Lower leg muscle Injury	1						
Gastrocnemius muscle injury/strain	3						
Soleus muscle strain	1						
Leg Soft Tissue Bruising/Haematoma	3						
Bone	1	0.09	[0 to 0.49]				
Ankle	**7 (12%)**	**0.62**	**[0.25 to 1.27]**	**3**	**(1.5 to 11)**	**13.05**	**[1.49 to 33.62]**
Muscle/tendon	1	0.09	[0 to 0.49]				
Cartilage/synovium/bursa	1	0.09	[0 to 0.49]				
Ligament/joint capsule	5	0.44	[0.14 to 1.02]	3	(1 to 13)	12.13	[0.62 to 32.87]
Joint sprain (ligament tear or acute instability)	5	0.44	[0.14 to 1.03]	3	(1 to 13)	12.13	[0.62 to 32.87]
Foot	**5 (8%)**	**0.44**	**[0.14 to 1.03]**	**2**	**(1 to 2)**	**0.88**	**[0.53 to 1.31]**
Muscle/tendon	1	0.09	[0 to 0.49]				
Ligament/joint capsule	1	0.09	[0 to 0.49]				
Vessels	3	0.26	[0.05 to 0.77]				
Contusion/vascular	3	0.26	[0.05 to 0.77]				

*Median time loss is only reported for categories with more than one case, Interquartile range (IQR) for time-loss days is only reported for subcategories containing five or more cases. Injury incidence rates, median time-loss days, and burden rates are only reported for specific diagnoses when there were five or more cases of that diagnosis. Non-specific diagnoses are not included.

Of the match injuries, 14 medical-attention injuries (28%) and 6 time-loss injuries (27%) were considered foul play, with one situation resulting in a yellow card for the opponent and two situations resulting in a red card for the opponent.

Illnesses

There were 41 reported medical-attention illnesses among 32 players (6% of participating players of this study) at an incidence of 4.2 per 1000 player-days [CI: 3 to 5.6]), and 8 time-loss illnesses among 8 players (IR: 0.8 per 1000 player-days [CI: 0.3 to 1.6]). The most affected organ systems were the respiratory system (16 medical-attention and 6 time-loss illnesses), genitourinary system (9 medical-attention and 3 time-loss illnesses), and gastrointestinal system (6 medical attention illnesses). Medical-attention illnesses were reported by 14 teams (median: 2, range: 1–14); 22 of the 41 medical attention illnesses were recurrences, 12 were index illnesses, and in 7 cases it was unknown whether the player had previously had the same illness. Time-loss illnesses resulted in 12 days lost in total (range 1–3 days per illness) and a burden of 1.2 days lost per 1000 player days [CI: 0.4 to 2.2].

Table 2. Pattern of time-loss injuries by tissue and pathology type.

	Injuries	Incidence rates		Median time loss		Burden rate	
	n (%)	New injuries/1000 h (95% CI)		Days (IQR*)		Days lost/1000 h (95% CI)	
Muscle/tendon	**27 (46%)**	**2.37**	**[1.56 to 3.45]**	**6**	**(3 to 9.5)**	**18.02**	**[11.34 to 26.63]**
Muscle injury	19	1.67	[1.01 to 2.61]	7	(4.5 to 10.5)	15.64	[9.32 to 23.64]
Muscle contusion	5	0.44	[0.14 to 1.03]	3	(3 to 3)	1.76	[0.88 to 2.64]
Tendinopathy	3						
Nervous system	**7 (12%)**	**0.62**	**[0.25 to 1.27]**	**7**	**(5.5 to 9)**	**4.22**	**[2.90 to 5.45]**
Brain/Spinal cord injury	7	0.62	[0.25 to 1.27]	7	(5.5 to 9)	4.22	[2.90 to 5.45]
Bone	**2 (3%)**	**0.18**	**[0.02 to 0.63]**	**91**		**16.00**	**[0.35 to 31.64]**
Fracture	1						
Bone contusion	1						
Cartilage/synovium/bursa	**5 (8%)**	**0.44**	**[0.14 to 1.03]**	**2**	**(1 to 9)**	**1.93**	**[0.53 to 3.34]**
Cartilage	4	0.35	[0.1 to 0.9]	1.5	(1 to 3.75)	1.14	[0.35 to 2.46]
Synovitis/capsulitis	1						
Ligament/joint capsule	**11 (19%)**	**0.97**	**[0.48 to 1.73]**	**9**	**(2 to 32.5)**	**23.29**	**[7.38 to 45.35]**
Joint sprain (ligament tear or acute instability)	11	0.97	[0.48 to 1.73]	9	(2 to 32.5)	23.29	[7.38 to 45.35]
Superficial tissues/skin	**1 (2%)**	**0.09**	**[0 to 0.49]**	**4**		**0.35**	
Vessels	**3 (5%)**	**0.26**	**[0.05 to 0.77]**	**2**		**0.44**	**[0.26 to 0.53]**
Contusion/vascular	3						
Non-specific	**3 (5%)**	**0.26**	**[0.05 to 0.77]**	**1**		**0.35**	**[0.26 to 0.53]**
Total	**59 (100%)**	**5.2**	**[4.0 to 6.7]**			**64.6**	**[30.8 to 110.4]**

*Interquartile range (IQR) for time-loss days is only reported for subcategories containing five or more cases. Injury incidence rates, median time-loss days, and burden rates are only reported for pathology type subcategories containing five or more cases.

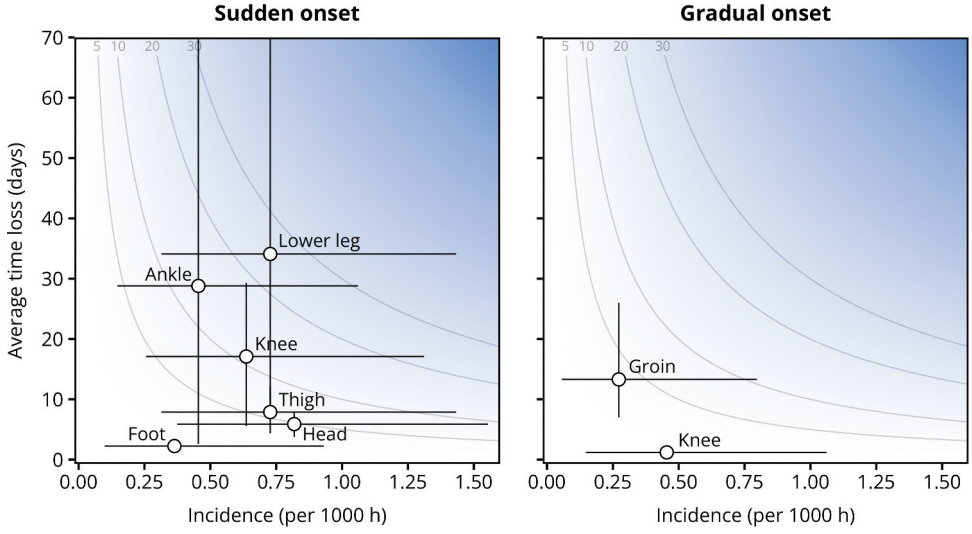

Figure 1. Risk matrices depicting the relationship between incidence rates and severity of time-loss injuries with a sudden onset (left panel) and a gradual onset (right panel). The darker the background colour, the greater the burden. The curved isobars depict an equal burden of 5, 10, 20 and 30 days lost per 1000 h. Vertical and horizontal error bars represent 95% CIs. Only body parts with >3 injuries are included in the figure.

Mental health problems

There were 4 reported mental health problems among 4 players. Of these, 2 newly incurred during the FWWC2023 (IR: 0.2 per 1000 player-days [CI: 0.02 to 0.7]), one of which led to 1 day of time-loss (IR: 0.1 per 1000 player-days [CI: 0 to 0.6]), and 2 were exacerbations of pre-existing conditions.

Discussion

Our study is the first to report medical attention injuries, illness, and mental health problems at international competition level of women's football consistent with recent consensus methodology recommended for the collection and reporting of injury and Illness epidemiological data in sport (Bahr et al. 2020; Waldén et al. 2023; Mountjoy et al. 2023). A total of 161 medical-attention injuries in 102 players, and 59 time-loss injuries in 55 players were reported. The most frequently injured areas were the knee, thigh, and head, with lower leg injuries causing the greatest overall time-loss injury burden. Relatively few illnesses were sustained during the tournament, mostly mild respiratory infections, and 2 new mental health problems were reported by the participating teams in this study.

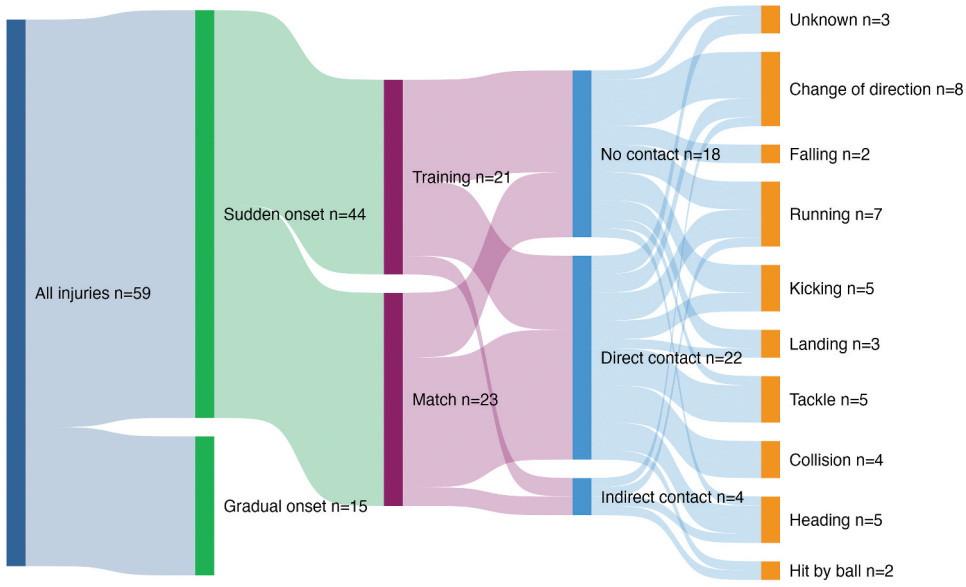

Figure 2. Distribution of the reported time-loss injuries by onset, setting, type of contact, and player action. The Sankey flow diagram stacks the subcategories i.e., nodes and illustrates the distribution of the injuries through the width of the arc as they flow through the nodes.

Injury incidence compared to other competitions

Comparing our findings to those reported from previous women's and men's major tournaments, and women's and men's leagues builds our understanding of population-specific epidemiology and informs the development of evidence-based prevention strategies (O'Brien et al. 2019). Injury surveillance during FIFA Women's World Cup tournaments has been ongoing since 1999, but FWWC2023 is the first major tournament to record medical attention injuries sustained during matches and training relative to individual player-level exposure (Appendix 3). A recent report of all health problems from the Norwegian women's premier league found that at any given time, 20% of players reported a substantial health problem due to injury, at an overall incidence of 8.4 injuries (CI: 7.7 to 9.2) per 1000 h of playing exposure (Amundsen et al. 2024). This contrasts with our overall medical attention injury incidence of 14.2 per 1000 h [CI: 12.1 to 16.6], which may be because our data was collected at a major tournament rather than over a full league season, or differing injury definitions. The Norwegian study found that muscle injury was the most common injury type, but ligament injuries caused the greatest burden, particularly ACL injuries (Amundsen et al. 2024). We also found that the knee and thigh were the most frequently reported injury locations, but the lower leg resulted in the highest overall time-loss injury burden. These findings emphasise the importance of measuring the impact on players of all injuries at major tournaments, not just those leading to time-loss.

The overall time-loss injury IR at FWWC2023 was 5.2 per 1000 h, very similar to that found at the 2022 FIFA Men's World Cup in Qatar (FWC2022) of 5.6 per 1000 h. However, the overall time-loss injury IR at FWWC2023 was lower than that found in the European women's elite club (UEFA) injury study of 6.7 injuries per 1000 h. Compared to previous professional football tournaments of both sexes, the time-loss match incidence from the FWWC2023 of 14.0 per 1000 h was relatively low (Junge and Dvorak 2013), with the equivalent time-loss match incidence at the FWC2022 being 21.6 per 1000 h (Serner et al. 2024). This may be a true reflection of lower match IRs for women playing at FWWC2023, or due to differences between the men's and women's games in terms of tactical injuries recorded during matches (Geertsema et al. 2021; Hallén et al. 2024). Of note, the UEFA study reported match time-loss IR of 18.4 per 1000 h, which is also higher than our FWWC2023 findings (Hallén et al. 2024). This contrasts with the findings in men's football where, apart from FWC2022, match IR has consistently been higher in international tournaments than in club football (Ekstrand et al. 2009; Junge and Dvorak 2013). Our study design could not examine factors to explain these different rates, but it could be hypothesised that the observed lower rate of match time-loss injuries may reflect higher levels of player physical preparation leading into the FWWC2023. Alternatively, the scheduled timing of the tournament may be a factor as it allowed for adequate recovery from the domestic league seasons which mostly ended in May/June 2023. There are likely to be many

contributors to these varying injury rates, and future prospective research examining the moderators and mediators of injury incidence in women's professional football is required.

Training injuries have rarely been reported in international women's competitions. Our findings of 2.2 time-loss injuries per 1000 h of training were similar to data obtained from men's professional players at the FWC2022 (2.1 per 1000 h of training) (Serner et al. 2024), and lower than the training time-loss incidence observed in the UEFA women's football study of 4.8 per 1000 h (Hallén et al. 2024). Lower training injury rates at the FWWC2023 were expected due to higher matches frequency likely leading to a focus on recovery and tactical sessions between matches and lower exposure to injury inciting mechanisms in comparison to a regular club season.

Injury distribution and severity

As expected, the lower limb dominated the most frequently reported and highest burden injury regions at the FWWC2023 (Junge and Dvorak 2007). The distribution of time-loss injuries by body area were similar to previous reports (Junge and Dvorak 2013), with the most common injured areas reported being the knee (0.96 per 1000 h), thigh (0.88 per 1000 h), and head (0.79 per 1000 h). The lower leg had the highest injury burden (22 days per 1000 h), primarily driven by a single severe lower leg muscle injury. A lower incidence and burden of thigh injuries in women compared to men has been consistently reported in professional football (Ekstrand et al. 2023; Hallén et al. 2024; Serner et al. 2024). In comparison to FWC2022 where thigh injury incidence was 1.67 per 1000 h and burden was 30.5 days per 1000 h, the relatively low rate in the FWWC2023 of 0.88 per 1000 h and burden of 6.1 days per 1000 h suggests that thigh muscle injuries may be less of a concern in the women's game. However, while thigh injuries created a lower burden for women's players than ankle (13.02 days per 1000 h) or knee injuries (10.92 days per 1000 h), they still represented the 4th highest injury burden, higher than that of head injuries (4.63 days per 1000 h).

Knee ligament injuries cause a high burden in women's professional football, with reports from UEFA and Norway of 41.7 and 41.4 days lost per 1000 h (Hallén et al. 2024; Amundsen et al. 2024). In the 2019 FIFA Women's World Cup, 20% of participants reported a history of ACL rupture (Geertsema et al. 2021). In FWWC2023, there were four new knee joint ligament injuries reported in our dataset (0.96 per 1000 h), with a median burden of 9.2 days per 1000 h, but none of these was ACL injuries. Despite the absence of ACL injuries in our FWWC2023 dataset, given their known high burden ongoing knee ligament injury prevention strategies should be prioritised.

Seven of the 9 injuries (78%) reported to the head region, were diagnosed as concussion. This equates to an IR of 0.79 per 1000 h, higher than that reported in the FWC2022 (0.14 per 1000 h) and the UEFA women's football study (0.2 per 1000 h). This relatively high rate of diagnosed concussion has been reported in previous injury studies of major women's football tournaments (Junge and Dvorak 2007, 2013), and may be due to increased recognition and caution regarding sports-related concussion diagnosis. However, women football players have previously been shown to have a higher incidence than males (Junge and Dvorak 2013; Blyth et al. 2021; Dave et al. 2022), report greater symptoms, and experience longer time-loss from sport following a concussion (Covassin et al. 2003; Blyth et al. 2021; Peek et al. 2024). Concussion in women football players may have a different mechanism than men, and further research exploring gender-related differences in both concussion mechanisms and recovery is recommended.

Injury onset and mechanism

Sudden onset medical attention and time-loss injuries were mostly from direct contact, with the most common mechanism being tackling by an opponent. This finding is consistent with previous video analyses of knee injury in female footballers which have found tackling to be the most common inciting event (Lucarno et al. 2021; Aiello et al. 2023). There may be opportunities to develop prevention strategies which particularly target safer tackling skills as has been successfully implemented in other women's football codes (Bruder et al. 2024). Throughout the tournament, 20 injuries were related to foul play with one yellow and two red cards. Given the low proportion of cards in these incidents, a review of the nature of foul play and potentially reducing the thresholds of penalising players may also assist in protecting player health.

Illnesses

Illness burden was relatively low at the FWWC2023, with only 8 illness resulting in time-loss accounting for a total of 12 days lost. Respiratory illnesses were the most frequently reported, consistent with previous reports (Bjørneboe et al. 2016). The ongoing vigilance around managing and preventing illness following the COVID pandemic may have been responsible for this low illness

burden. Funding for FWWC2023 mostly allowed for single occupancy accommodation for players which may have also contributed to a low transmission of illnesses between players.

Mental health problems

Ours is the first study to monitor mental health problems in an international football tournament. The FIFA Women's World cup is the most prestigious tournament for female footballers and the high pressure of performing at this international level can induce intense emotions. Players may experience new mental health symptoms or the high pressure environment may exacerbate existing problems (Reardon et al. 2019; Sarmento et al. 2021; Mountjoy et al. 2023). Although our data suggests low rates of mental health problems were experienced at the FWWC2023, the exclusion of the pre-existing mental health problems may have underestimated the true impact of mental health problems in these players. The potential underestimation of the effect of mental health problems on athletes warrants reconsideration of measurement methods in surveillance reports. Different methods may be required to truly capture and measure the effect of mental health problems on athletes during major competitions.

Strengths and limitations

Our study followed the current recommended methodology of injury and illness surveillance in football (Bahr et al. 2020; Waldén et al. 2023; Mountjoy et al. 2023). Using a medical attention definition and recording training and match injures, illnesses, and mental health problems, we aimed to provide a comprehensive picture of all health problems affecting players at the tournament.

One of the main limitations of our study is that not all teams and players provided consent to participate. As we do not suspect any association between players' willingness to participate in surveillance and their injury risk, it is unlikely that our main outcomes are substantially biased by non-participation. However, our data clearly do not represent a complete account of all injury and illness that occurred at FWWC2023, and our outcomes should be interpreted with care. Efforts are needed to better understand barriers and facilitators to participation in surveillance projects. Concerns over data security, difficulty reporting, understanding of research, time concerns, language barriers, and cultural factors need consideration. We attempted to minimise these barriers by distributing a surveillance guide, translated into four languages, prior to the tournament. Each country participating in the study was teamed up with surveillance officers who had common language skills where possible. However, wide variation in medical attention injury reporting between included teams (n = 1–58) indicated that reporting bias is likely to have occurred. Greater time and effort may be required educating team medical staff on the surveillance requirements and injury definitions, to obtain more accurate data. A large team of international clinical researchers worked collaboratively with stakeholders to develop surveillance methodology with current standardised definitions and user-friendly methods which minimised time burden for data collection. The learnings from this process will allow this methodology to be applied in future tournaments and allow direct comparison of epidemiological data.

Other methodological limitations to be considered are standard to all single competition studies where due to the short observation time, and relatively small number of injuries recorded, individual injuries had a large effect on certain outcomes. Further limitations surround the health problem definition and exclusion of exacerbation cases. Ten injuries, 7 illnesses, and 2 mental health problems were excluded from analyses as they were exacerbations of pre-existing (unresolved) problems that did not comply with our health problem definition. This highlights a methodological challenge for recording mental health problems, with half of the recorded problems being excluded, including one that led to 40 days of time-loss, but also chronic illnesses and injuries. This challenge calls for improved monitoring and management between clubs and national teams to continuous prevention strategies as highlighted by participants of the FIFA Women's World Cup France 2019™ (Geertsema et al. 2021).

Conclusion

Injury incidence and burden at the FWWC2023 was lower than reported at previous international football tournaments of both sexes. Following new consensus recommendations, we have built on the existing body of knowledge by adding findings related to training injuries, illness, mental health problems and injury mechanisms in this population. This provides opportunities to monitor trends over time using standardised methodology and protect the health of women footballers playing at international competition.

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Data availability statement

The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research supporting data is not available.

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