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Injury Incidence, Severity, and Type Across the Menstrual Cycle in Female Footballers: A Prospective Three Season Cohort Study

ALLY BARLOW[1], JOANNA M. BLODGETT[2], SEAN WILLIAMS[1], CHARLES R. PEDLAR[2,3,4], and GEORGIE BRUINVELS[2,3,4]

[1]Centre for Health, and Injury & Illness Prevention in Sport, Department for Health, University of Bath, Bath, UNITED KINGDOM; [2]Institute of Sport, Exercise and Health, Division of Surgery and Interventional Science, University College London, UNITED KINGDOM; [3]Faculty of Sport, Allied Health and Performance Sciences, St Mary's University, Twickenham, UNITED KINGDOM; and [4]Orreco Ltd. Business Innovation Centre, University of Galway, Galway, IRELAND

ABSTRACT

BARLOW, A., J. M. BLODGETT, S. WILLIAMS, C. R. PEDLAR, and G. BRUINVELS. Injury Incidence, Severity, and Type Across the Menstrual Cycle in Female Footballers: A Prospective Three Season Cohort Study. *Med. Sci. Sports Exerc.*, Vol. 56, No. 6, pp. 1151–1158, 2024. **Purpose:** The aim of the study was to assess the influence of menstrual cycle phase on injury incidence, severity, and type in elite female professional footballers over three seasons. **Methods:** Time-loss injuries and menstrual cycle data were prospectively recorded for 26 elite female football players across three seasons. The menstrual cycle was categorized into four phases using a standardized model: menstruation (phase 1; P1), remainder of follicular phase (phase 2; P2), early luteal (phase 3; P3), and premenstrual phase (phase 4; P4). Injury incidence rates (IIR) and ratios (IIRR) were calculated for overall injuries, injury severity, type, contact vs noncontact, and game/training. **Results:** A total of 593 cycles across 13,390 d were tracked during the study, and 74 injuries from 26 players were eligible for analysis. When comparing IIR between phases (reference: P1), overall injury rates were highest in P4 (IIRR, 2.30 (95% confidence interval, 0.99–5.34; $P = 0.05$)). When examining rates by injury severity and type, IIR values were also highest in P4 for ≤7 d' time-loss (4.40 (0.93–20.76; $P = 0.06$)), muscle-specific (6.07 (1.34–27.43; $P = 0.02$)), and noncontact (3.05 (1.10–8.50; $P = 0.03$)) injuries. Muscle-specific (IIRR P3/P1, 5.07 (1.16–22.07; $P = 0.03$)) and ≤7 d' time-loss (4.47 (1.01–19.68; $P = 0.05$)) injury risk was also significantly higher in P3. Muscle injuries were the most prevalent subtype ($n = 41$). No anterior cruciate ligament injuries were recorded across the monitoring period. **Conclusions:** Injury risk was significantly elevated during the luteal phase of the menstrual cycle (P3 and P4) among elite female professional footballers. Further research is urgently needed to better understand the influence of the menstrual cycle on injury risk and to develop interventions to mitigate risk.

Key Words: ATHLETES, EPIDEMIOLOGY, WOMEN, SOCCER, MUSCLE, HORMONES

Elite female football has recently seen a large increase in popularity and attention, which has facilitated greater professionalization of the game. This has resulted in an increased standard of play, more media coverage, and more research attention from a medical and performance perspective (1). Despite this, females are reported to have 21% less availability than males, primarily due to a greater incidence of severe ankle and knee ligament problems (2). For example, anterior cruciate ligament (ACL) injuries are up to eight times more prevalent in females than male counterparts (2–4).

It has been suggested that the menstrual cycle could modify injury risk in female athletes (5). Female sex hormones fluctuate throughout the menstrual cycle and can change by over 100% in 24 h (6). These cyclical variations in endogenous hormones can have systemic effects, including influencing musculoskeletal tissue such as the muscle, tendon, and bone (5,7). Females must adjust and adapt to these hormonal changes, and this can affect readiness to play, with 51%–93% of female athletes self-reporting performance detriments or negative experiences associated with the menstrual cycle (8,9). Several studies have shown a greater incidence of ACL injury in the late follicular phase when estrogen concentrations are at their peak (10–12). There are a number of potential hypotheses for this, including an increased ACL laxity in response to high levels of estrogen (5). However, evidence is inconsistent, as some studies have also shown greater ACL injury incidence in the early follicular or late-luteal phases (13,14). Studies focusing on mechanisms of other injury types in female sport are

Address for correspondence: Georgie Bruinvels, Ph.D., Institute of Sport, Exercise and Health, Division of Surgery and Interventional Science, University College London, WC1E 6BT, United Kingdom; E-mail: georgie.bruinvels.14@ucl.ac.uk.
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lacking despite recognition in the literature of the anatomical, physiological, and physical sex differences. It is plausible that the hormonal changes could alter biomechanics and movement patterns, which could create other injury risk windows; for example, studies have found altered postural sway and plantar fascia laxity when estrogen levels are at their peak (15,16). Furthermore, increased amino acid turnover associated with high concentrations of progesterone could also create another window of susceptibility where the balance between muscle anabolism and catabolism is compromised (17).

To the knowledge of the authors, only two studies have examined all injury subtypes in women's team sports in parallel with menstrual cycle data (10,18). Both studies applied a three-phase approach, relied on inconsistent tracking (e.g., international camps spread over a 4-y period), and had players self-calculate menstrual phase. One study concluded a greater risk of muscle and tendon injury in the late follicular phase, just before predicted ovulation (18) and the other in the follicular phase (19). This latter study, however, did not exclude those using hormonal contraceptives, which may have confounded results (19).

Research around the menstrual cycle has been limited by a lack of a standardized approach to prospective data collection and analysis. Some studies are confounded by the inclusion of combined hormonal contraceptive users, where exogenous hormones downregulate the natural hormonal (endogenous) rhythm (12–14,20,21). Another issue is that the definition of menstrual cycle phases varies between studies from the most simplistic (two phases) to the highly detailed (seven phases) (21). Problems also arise with the challenges of collecting "real-world" data on athletes, where regularly taking invasive or inconvenient measures is not feasible. The three-phased model in the two studies described previously comprised the menstrual phase (low estrogen and progesterone; early follicular phase), preovulation phase (high estrogen; late follicular phase), and the luteal phase (high estrogen and progesterone). Applying this approach means that the premenstrual phase, notably a time where hormones dramatically decline, resulting in a multitude of systemic effects and where symptoms are common, is not separated from the high hormone, early and midluteal phase. Therefore, in the present study, a four-phased model was applied based on assumed hormonal changes to account for this including; menstruation (early follicular), mid-late follicular, early- to mid-luteal and premenstrual (late luteal). By separating the cycle into more phases based on assumed hormonal profiles, it should allow for improved sensitivity in identifying any meaningful changes. For best accuracy in determining phases, endogenous reproductive hormonal measurements should be taken as a "gold standard" approach (21). However, in an applied setting, this can be challenging, particularly where athletes are being tracked longitudinally over an extended period, for example., multiple seasons (22). The practicalities of regular hormone measurements, including the athlete burden, staffing burden, associated challenges around sample collection and storage, the required financial resource, in addition to a clear need to justify this to the coaching staff means that at present, with the current methods for hormone measurement, this is likely to be unrealistic on an ongoing continual basis. There are strengths and limitations to both approaches that much be considered. Because menstruation (onset of menstrual bleeding) is a clear-cut point, this phase is easily determined, as is the premenstrual phase, which is just before the onset of menstruation. Previous studies have employed a regression equation to estimate peak luteinizing hormone concentration based on total cycle length (23) to enable a further phased breakdown of the menstrual cycle separating out the estimated follicular phase from the luteal phase. This approach has been used in previous studies (18), and a similar approach will be employed in the present study.

To date, the incidence of injury, severity, and type in elite footballers has not been studied longitudinally alongside the menstrual cycle. Therefore, the aim of this study is to investigate whether injury incidence, severity, and type significantly differ across the four phases of the menstrual cycle in a cohort of elite female footballers over three seasons.

METHODS

Participants. Professional female footballers 18 y and older, contracted to a single professional English Women's Super League football club between June 2019 and May 2022, were invited to participate in the study. For inclusion in the study, players needed to have been eumenorrheic (10–16 periods per year for 12 months before the beginning of the study [24]) and provided at least one season worth of menstrual cycle and injury data. Players were excluded if they were using combined forms of hormonal contraception, premenarchal, oligomenorrheic, or amenorrhoeic (absence of menstrual bleeding for >90 d during the reproductive years [25]). To determine if players were eligible for inclusion, all players completed a female health screen during preseason each year, among a range of other female health-specific questions, this captured 1) the number of periods experienced in the last year, 2) use of hormonal contraception, 3) previous diagnosis of menstrual dysfunction, and 4) menstrual cycle–related symptoms. Users of low concentration progestin-only hormonal contraception who experienced regular bleeds (every 21–35 d) were included in the analysis because negligible systemic metabolic disturbances have been observed with use of this form of contraception (26). Of 35 individuals, 5 players were excluded due to not providing consent and 4 players were excluded due to not meeting the inclusion criteria. In total, the present study included 26 participants and 593 tracked menstrual cycles. Before recruitment, players were provided with information about the research including terms of involvement. Informed consent was obtained before data analysis began. Participants were informed that they could withdraw their data up to the date of data anonymization without consequence. Ethical approval was granted by MSc SEM & SPY Research Ethics Approval Committee (at the University of Bath).

Data Collection. This study utilized injury and menstrual cycle data that were prospectively collected over a 3-y period. Injury data were collected by medical practitioners at the club and stored securely per European General Data Protection Regulation guidelines on the medical server at the club. Menstrual cycle data were collected using a mobile menstrual cycle tracking application, in accordance with European General Data Protection Regulation guidelines (FitrWoman, Orreco, Ireland). A data sharing agreement between the club and the university was established to allow the data to be included in this research following individual player consent to inclusion.

Injury recording and player availability. An injury was defined as an incident that prevented a player from taking part in full training or match-play for one or more days following the injury (27). Injuries sustained outside formal training or match-play were excluded from analysis. Injury information was recorded by the football club's medical support staff and logged on an electronic medical records system (Kitman Labs, Dublin, Republic of Ireland). Each injury was classified using the Orchard Sport Injury Classification System (version 10) (28). Injury severity was defined as the number of days of training and match play missed due to the injury sustained. Player availability status was recorded daily across the study period; one person-day indicated that an individual player participated in a training session or match. No injuries were sustained outside of training or match play.

Menstrual Cycle Data. Players were screened on recruitment to establish whether they were using hormonal contraception or had any signs of menstrual dysfunction (e.g., amenorrhea). Female health data were tracked longitudinally throughout the study; therefore, any changes in menstrual status or use of hormonal contraception were carefully monitored. Throughout the study period, players tracked their own menstrual cycle data, recording menstruation days and intensity of flow. This information was accessible to medical support staff via a specific coaching platform. The mobile tracking application uses an integrated algorithm using a standardized model to divide the cycle into four phases based on an assumed hormonal profile. Briefly, menstruation was classified as phase 1. The remainder of the predicted follicular phase was classified as phase 2, phase 3 was the majority of the luteal phase, and phase 4 was the premenstrual window, defined as the 5 d before the onset of menstruation. Phases 2, 3, and 4 were retrospectively calculated based on cycle length. The calculation of phases 2 and 3 was established by applying a comparative approach to the regression equation used to predict luteinizing hormone peak defined by McIntosh et al. (23) in 1980 where phase 2 made up the days from menstruation to the predicted peak and phase 3 the days after the predicted peak before the start of phase 4, the premenstrual phase. This calculation is built into the tracking app and utilized by the players. Only menstrual cycles tracked during the season were included in the analyses.

Female Health Support. On initiation of monitoring, all players received female health education led by the nominated "female health lead" for the club (a sports scientist with a research and applied focus on female physiology) and completed a female health screening questionnaire that was analyzed by the female health lead, the medical doctor, and other relevant members of the multidisciplinary team. Any potential medical flags from the questionnaire were identified by the medical doctor and, where relevant, referred to an appropriate practitioner. Players were aware that female health screening and tracking, with medical referral if necessary, was standard practice at the club, although there are able to opt out at any time. On arrival at the club, new players received female health education, which included information about why and how to track and monitor cycles. Players were then tracked longitudinally by a nominated physiotherapist alongside the female health lead for the club, and any concerns or abnormalities were discussed with the relevant practitioner(s) from the multidisciplinary team. In the case of potentially missing menstrual cycle tracking data, the player would be contacted ("checked in" with) to establish if there was a health issue or adherence issue. Any medical concerns were reported to the team doctor.

Statistical Analysis. Descriptive statistics were used to describe the frequency of total injuries, injury type, and injury severity within each menstrual cycle phase. The distribution of continuous variables was assessed for normality using the Shapiro–Wilk test. Given the differences in cycle length both within and between individuals, the frequency of injury was also visualized across cycle progression (where day 1 of menstruation was considered 0% and the final day before menstruation was 100%), derived from the cycle length of the previous three full cycles. Percent of cycle progression was utilized for visualization only and not for subsequent analysis. Person-days were quantified by summing the number of days of training/game participation from all individual players. This was calculated for each menstrual cycle phase and used to estimate injury incidence rate (IIR) per 1000 person-days for each phases (29). Injury incidence rate ratios (IIRR) were calculated by comparing IIR between phases, using phase 1 as the reference category. Finally, IIR and rate ratios were also calculated by injury severity and type. To assess statistical significance of the incidence rate ratios, we conducted Wald chi-square tests using an alpha of 0.05 (30). Analyses were carried out in Jamovi (V2.3) and Stata MP 17.0.

RESULTS

Player characteristics. Player availability (e.g., nonrest days) and menstrual cycle data were recorded for a total of 13,390 d across the total study period; this included a total of 593 cycles tracked (mean cycle length, 29 ± 5 d) and an average of 239 ± 41 d per player per season. During this time, 7273 training and match person-days were eligible for inclusion in analysis; illness, nonselection for matches, and international break windows were not included for analysis. The average age of the 26 included players at baseline was 24.1 ± 4.6 y.

Description of injuries and cycle length. A total of 74 eligible injuries occurred across the study period (mean, 2.86 ± 2.40; median, 2 (quartile 1: 1, quartile 3: 3.5). Muscle injuries were the most common (n = 41; 55.4%), followed by joint and ligament (n = 15; 20.2%), tendon (n = 7; 9.5%), fracture and bone stress (n = 7; 9.5%), and central/peripheral nervous system injuries (n = 4; 5.4%). A majority of injuries were noncontact in nature (n = 55; 74.3%), with more injuries occurring during games (n = 42; 56.8%) than training (n = 32; 43.2%). Injury severity ranged from 2 to 220 d with a median of 8 (quartile 1: 1.25, quartile 3: 14.75) d. The average cycle length when injury occurred was 29.9 ± 4.6 d, whereas the average cycle length from the 3 months preceding injury was 29.5 ± 3.4 d.

Not standardizing for phase length, more injuries occurred in phases 2 (n = 26) and 3 (n = 23) compared with phase 4 (n = 17) and phase 1 (n = 8). Figure 1A shows the distribution of injuries across each day of the cycle, whereas Figure 1B shows the distribution of injuries across cycle progression (i. e., as a proportion of each individual's average cycle length). Across both methods, there was a slight increase in injuries on days 4–8 (or ~20%–40% into the cycle), with a more substantial peak around days 21–24 (or ~70%–90% into the cycle).

Injury incident rates and rate ratios. Table 1 summarizes the frequency and IIR across each menstrual cycle phase and provides incidence rate ratios comparing rates from phases 2, 3, and 4 to phase 1. When using standardized incidence rates, injuries were least common in phase 1 (6.1 injuries per 1000 person-days; Table 1) and increased across the cycle (phase 2: 9.9, phase 3: 10.9, phase 4: 14.0). IIRR showed that injuries occurred 2.30 (95% confidence interval [CI], 0.99–5.34; P = 0.05) times more frequently in phase 4 compared with phase 1. Although IIRR also suggested that injury rates were higher in phase 3 (1.79; P = 0.16) and phase 2 (1.62; P = 0.23) compared with phase 1, this was not statistically significant.

Further investigation by injury type suggested that muscle injuries were more common in phases 3 and 4 (7.6 and 9.1 injuries per 1000 person-days) than in phases 1 and 2 (1.5 and 4.6 injuries per 1000 person-days). Using phase 1 as the reference, muscle injury rates were 3.07 (0.69–13.72; P = 0.14) times higher in phase 2, 5.07 times higher in phase 3 (5.07 (1.16–22.07); P = 0.03), and 6.07 times higher in phase 4 (6.07 (1.34–27.43); P = 0.02). IIR values were similar for joint and ligament injuries across all phases (range, 1.4–2.3 per 1000 person-days; P > 0.05), whereas ratios were not calculated for fracture and bone stress or central/peripheral nervous system subcategories due to the limited number of the injuries of this type. Noncontact injuries were more prevalent (n = 55) than contact injuries (n = 19); IIRR suggested that noncontact injury rates were higher in phase 4 compared with phase 1

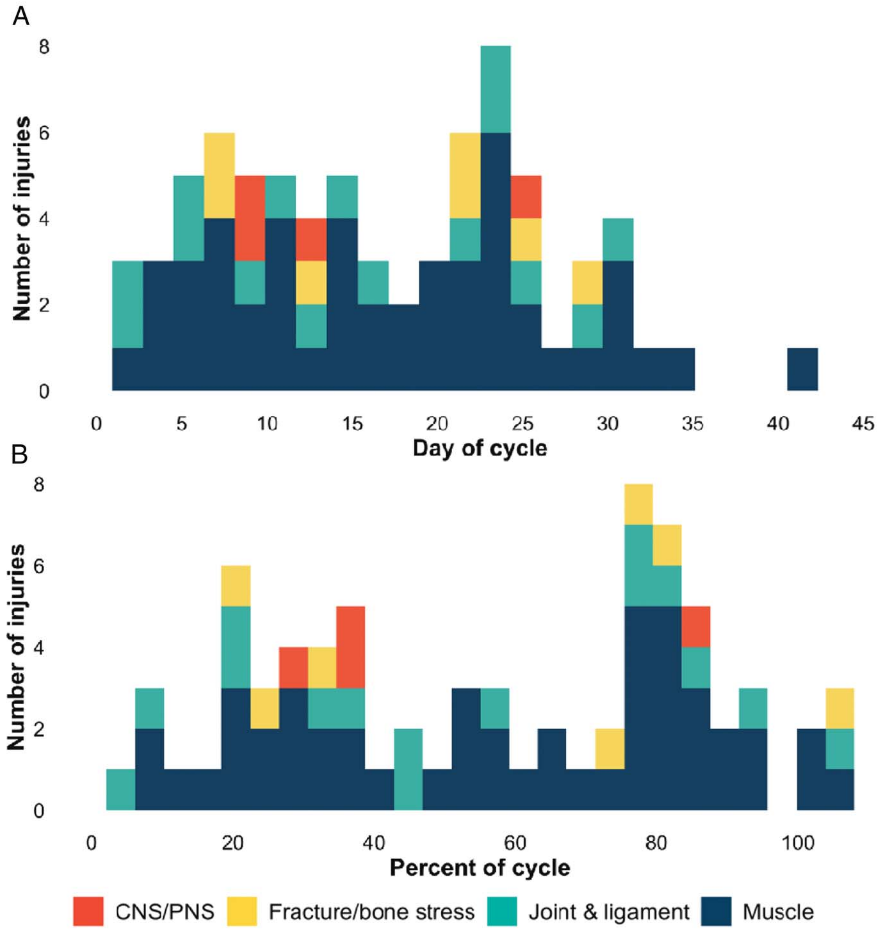

FIGURE 1—Stacked histogram demonstrating injury occurrence across (A) menstrual cycle day (where 1 = first day of menstruation) and (B) menstrual cycle progression (where 0% = first day of menstruation, 100% = final day before next menstruation).

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TABLE 1. Total number of injuries, IIR, and IIRR across all injuries and by injury type.

	Total No. Injuries					IIR (per 1000 person-days)				IIRR (95% CI, P Value) (Ref: Phase 1)		
	Total	Phase 1	Phase 2	Phase 3	Phase 4	Phase 1	Phase 2	Phase 3	Phase 4	Phase 2:1	Phase 3:1	Phase 4:1
All injuries	74	8	26	23	17	6.1	9.9	10.9	14.0	1.62 (0.73–3.59), P = 0.23	1.79 (0.80–4.01), P = 0.16	2.30 (0.99–5.34), P = 0.05
Injury type												
Muscle	41	2	12	16	11	1.5	4.6	7.6	9.1	3.07 (0.69–13.72), P = 0.14	5.07 (1.16–22.07), P = 0.03	6.07 (1.34–27.43), P = 0.02
Joint and ligament	15	3	6	3	3	2.3	2.2	1.4	2.5	0.96 (0.24–3.83), P = 0.95	0.61 (0.12–3.02), P = 0.54	1.09 (0.22–5.40), P = 0.92
Tendon	7	3	2	1	1	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]
Fracture and bone stress	7	0	3	2	2	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]
Central/peripheral nervous system	4	0	3	1	0	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]
Contact												
Contact	19	3	9	4	3	2.3	3.4	1.9	2.5	1.4 (0.40–5.47), P = 0.56	0.83 (0.18–3.70), P = 0.80	1.09 (0.22–5.40), P = 0.92
Noncontact	55	5	17	19	14	3.8	6.5	9.0	11.6	1.71 (0.63–4.65), P = 0.29	2.37 (0.88–6.36), P = 0.09	3.05 (1.10–8.50), P = 0.03
Session type												
Game	32	3	8	13	8	2.3	3.1	6.2	6.6	1.35 (0.36–5.09), P = 0.66	2.70 (0.77–9.48), P = 0.12	2.87 (0.76–10.84), P = 0.12
Training	42	5	18	10	9	3.8	6.9	4.8	7.5	1.82 (0.67–4.90), P = 0.24	1.26 (0.43–3.70), P = 0.67	1.97 (0.66–5.91), P = 0.22
Severity (d)												
1–7	35	2	11	14	8	1.5	4.2	6.7	6.6	2.80 (0.62–12.65), P = 0.18	4.47 (1.01–19.68), P = 0.05	4.40 (0.93–20.76), P = 0.06
8–14	16	1	7	5	3	0.8	2.7	2.4	2.5	3.38 (0.41–27.46), P = 0.26	3.00 (0.35–25.71), P = 0.32	3.12 (0.32–30.08), P = 0.32
15–28	11	3	3	3	2	2.3	1.1	1.4	1.7	0.48 (0.10–2.37), P = 0.37	0.61 (0.12–3.02), P = 0.54	0.74 (0.12–4.43), P = 0.74
>28	12	2	5	1	4	1.5	1.9	0.5	3.3	1.27 (0.25–6.54), P = 0.78	0.33 (0.03–3.68), P = 0.37	2.20 (0.40–12.03), P = 0.36

[a] Could not calculate because of insufficient injuries in these categories. Note: CI values are calculated in reference to phase 1 difference.

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(3.05 (1.10–8.50); $P = 0.03$), with no difference in contact injury rates across phases (all $P > 0.05$). There was no indication that IIR differed across phases for more severe injuries (i.e., >7 d). However, when examining minimal/mild injury (i.e., 1–7 d lost), IIR values were 4.47 (1.01–19.68; $P = 0.05$) times higher in phase 3 and 4.40 (0.93–20.76) times higher in phase 4 compared with phase 1.

DISCUSSION

The present study assessed the influence of menstrual cycle phase on incidence, severity, and type of injury. Of the 74 injuries that occurred, muscle injuries were the most common, and injury incidence was greatest in phase 4 of the menstrual cycle (premenstrual phase), where 14 injuries occurred per 1000 person-days. When compared with phase 1, the incidence of muscle injuries was over three times more likely in phase 2, over five times more likely in phase 3, and over six times more likely in phase 4.

In contrast to our study, Lago-Fuentes et al. (19) used a three-phased menstrual cycle model including follicular, ovulatory, and luteal phases to evaluate incidence of injury in elite female futsal players. When comparing injury incidence between phases, the highest incidence of injury occurred within the follicular phase, followed by the luteal phase, with lowest incidence in the ovulatory phase. Other studies have also observed greater injury incidence in the follicular phase, but these have only included ACL injuries (31,32). Another recent study, applying a three-phased model specifically looking at injuries in women's football (18), found a higher incidence of injury, and specifically muscle and tendon injuries, within the late follicular phase. This finding is similar to Lago-Fuentes et al. (19), both of which contradict findings from the present study.

The conflicting results from these studies when compared with the present study could be due to several factors. First, it should be acknowledged that there will naturally be different approaches to movement programs, loading, nutrition, and female health support within different clubs and sports, which could also be a cause for the differing results in the present study. Also, there is potential for ambiguity of menstrual cycle reporting, in the previous research by Martin et al. (18) and Lago-Fuentes (19), as this was based on recall (18) or self-calculation (19). These approaches lead to more opportunity for error and potentially misclassifying the phase of injury. Similar to the present study, ovulation testing was not conducted, which prevents the precise calculation of an ovulation phase. A significant strength of the present study, however, is that cycles were continuously tracked and phases were calculated objectively using an established algorithm calculated through a menstrual health app; therefore, there was no recall bias in data collection.

The severity of ACL injuries has led to much research focus on this area; however, no ACL injuries were recorded in the present dataset during the 3-y monitoring period. In fact, the present data highlight the need to consider other injury types, particularly muscle-based injuries given the patterns of results shown here. Relatively few joint and ligament injuries ($n = 15$) were recorded in the current study, and these were evenly distribution across the four phases (phase 1 = 2.3/1000 person-days, phase 2 = 2.3/1000 person-days, phase 3 = 1.4 per 1000 person-days, phase 4 = 2.5/1000 person-days). However, more data are needed to better understand if there is an association between ligamentous injury and menstrual cycle phase; given the relative low prevalence of ACL injuries compared with muscle injuries, future study design must consider a larger sample size (e.g., several leagues rather than a single team).

There were more injuries observed in phases 3 and 4 in the present study (luteal phase). Specifically, the greatest incidence of injury was in phase 4. When considering injury type, muscle injuries showed the most variation across phases but were most common in phase 4. Speculatively, there are several potential causes for the increased prevalence of muscle injuries here. First, the higher levels of progesterone in the second half of the cycle (phases 3 and at the beginning of phase 4) have been associated with increased amino acid catabolism (17), because skeletal muscle is a primary site for amino acids storage and increased turnover of these amino acids can reduce anabolic properties, which could potentially increase the risk of muscle injury when under repeated training stress (33). It is, however, important to interpret these results with caution as we did not collect data to indicate an increase in progesterone in the estimated luteal phase. Second, and more specifically in the premenstrual window, the withdrawal of hormones premenstrually, where there is a transition from high to low estrogen and progesterone, results in the upregulation of proinflammatory pathways and an increased expression of inflammatory mediators such as prostaglandins, which are essential for the breakdown of the endometrial lining (34). The effects appear to be systemic, with a number of studies demonstrating elevated levels of inflammatory biomarkers perimenstrually (33–35). This could delay or extend recovery times, which could affect recovery and induce a state of overload by compromising tissue integrity and increase the risk of injury. Importantly, the premenstrual window (phase 4) is where adverse menstrual cycle symptoms often occur; sleep disruption, altered mood, reduced coordination, and lower back pain are all frequently reported (8,36). These could potentially compromise readiness, movement patterns, and recovery, also increasing injury risk. Finally, hormonal changes are also likely to affect soft tissue action, by altering movement patterns that could increase risk at particular time points (5,15,16). Taken together, there are several potential reasons a decline in hormones during phase 4 may be a factor in increasing muscle injury risk.

It is also notable that noncontact injuries were also three times more likely to occur in phase 4 versus phase 1. This could be associated with the effects of the hormonal withdrawal in phase 4. This is particularly notable as it is hypothesized that noncontact injuries are more preventable than contact injuries. This could be associated with the mechanisms described in the previous paragraph, and it is of particular note that phase 4 is where hormones acutely decline as part of the process to cause the breakdown of the endometrial lining (33). Further research is needed to track inflammation and symptoms, and understand

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individual player phenotypes and other factors of readiness such as sleep, alongside the menstrual cycle phases to more completely understand the most important covariates of injury risk. Building a multidimensional profile of female athletes from a medical, physiological, physical, and holistic perspective would facilitate a better understanding of the potential injury considerations and lead to better player care.

Despite the study being underpowered (confined to one team), we observed significantly higher rates of injury in phase 4 and lower rates in phase 1. The findings here should be interpreted with caution, as a larger sample size is needed from multiple teams before making more definitive inferences to practice. A sample size calculation (in the *epiR* package) based on the low injury incident rates of phase 1 (6.1 per 1000 person-days) and phase 4 (14.0 per 1000 person-days) reported previously, alpha of 0.05, power of 0.80, and average of 240 d of follow-up per season requires a minimum of 84 players to be followed up over a single season. Because of a small sample size, we were unable to explore how IIR and IIRR differed by first-time and recurrent injury status; this area warrants further investigation. However, the number of recurrent injuries was small ($n = 5$), with some spanning multiple seasons, and we hypothesize that similar mechanisms may have contributed to the aggravation of these injuries.

This study indicates the potential value of monitoring the menstrual cycle and paves the way for future research to better identify how to support improvements in performance and reduce injury incidence in female athletes. The findings here suggest that it is crucial to collect continuous menstrual cycle data alongside standardized and comprehensive injury data. Notably, existing published guidelines for injury recording have no recommendation for the inclusion of information on the menstrual cycle (37). A consensus on how this information is collected needs to be established to allow large-scale collection and collaboration of useful and comparable data. Players need to be available to train and play on any given day in their cycle; therefore, proactive management around the menstrual cycle such as cycle tracking, providing symptom support and education around nutrition, sleep, and recovery, should be considered on an individual basis, factoring in the presentation of their unique cycles. Future research should also consider ways this can be managed across the multidisciplinary team. Despite much discussion focusing on ACL injuries in women's sport, the findings here highlight that other injuries also need to be considered in female athletes. Given the association with muscle injuries and the menstrual cycle, future research should also capture self-reported symptoms alongside these as a potential means of risk mitigation.

Limitations. There are some limitations that should be noted when interpreting the results of this study. The homogenous nature of the population, all being from a single club, is a clear strength of this study; however, it may also lead to reduced generalizability as the included players were exposed to the same football environment, playing surfaces, training design, and injury prevention protocols for the duration of their inclusion in this research.

Although the study was conducted over three seasons and includes a greater number of cycles tracked and more person-days than previous studies linking menstrual cycles to injuries, the numbers remain relatively small, especially when categorizing injuries into subtypes and studying incidence, severity, and type across 4 phases. Replicating this study design on a greater scale would require multiple teams to participate. Hormones were not tracked in this study, and there are clear limitations to calendar-based counting methods. However, at present, the invasiveness and expense of collecting these measures longitudinally (i.e., over three seasons) are extremely challenging and impractical in an elite, high-performance environment. In time, as technology evolves to increase accuracy of low-friction monitoring, research accuracy will significantly improve.

CONCLUSIONS

This is the first study to prospectively investigate injury incidence, severity, and type across 4 phases of the menstrual cycle in elite female footballers. Overall injury incidence and specifically muscle injury incidence were highest in the premenstrual phase, with lowest risk observed during menstruation. This needs to be further investigated on a larger scale; however, this study demonstrates a rationale for tracking menstrual cycles as a part of routine female athlete care. Presently, with female participation in football and interest in the game globally at an all-time high, the need for further understanding and investigation surrounding the impact of the menstrual cycle on injury is paramount (35). Elite female athletes need to be able to perform optimally on every day of their cycle, so understanding the day-to-day variations of hormone cycles and their potential impact on injury and ways to mitigate this is necessary for practitioners to provide appropriate support.

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G. B. and C. R. P. work for Orreco, a sports science consultancy company who have produced the free menstrual tracking app FitrWoman and the coaching app FitrCoach.

The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results from the present study do not constitute endorsement by the American College of Sports Medicine.

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EDI statement: Our research and author team included three female authors and two male authors, consisted of midcareer researchers and experienced senior researchers from different disciplines with three countries and two continents represented. The first and senior authors are both women.

Our study was on female football players. Our study population included females of different race, culture, ethnicity, and socioeconomic level and included representation of marginalized groups such as women of color, women from the LGBTQIA2S+ community, and women from middle-income countries.

Contributors: A. B., G. B., and S. W. conceptualized the research study aims and methodology; A. B., G. B., and J. M. B. curated, reviewed, and categorized all data provided by the football club; A. B. and J. M. B. conducted the formal statistical analysis; A. B., G. B., J. M. B., and C. R. P. wrote the manuscript; all authors reviewed and approved the final manuscript.

Data sharing statement: The data included in this study will not be made publicly available to protect athlete confidentiality.

Patient and public involvement: Patients or members of the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

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