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Menstrual Cycle Characteristics and Sports Injury History Among Competitive Female Athletes: A Cross-Sectional Study

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Abstract

Background: This study examined associations between menstrual cycle characteristics and sports injury history among competitive female athletes.

Methods: This cross-sectional study included 250 female athletes aged 18–30 years from nine sports. Menstrual characteristics were self-reported. Injuries causing ≥3 days of time loss during the preceding year

were medically confirmed. Analyses used chi-square tests and logistic regression adjusted for age, body mass index, playing experience, and training duration.

Results: The mean age of participants was 24.19 ± 3.78 years. Overall, 53.2% had at least one confirmed sports injury during the preceding 12 months, with lower-limb injuries in 38.0%. Menstrual irregularity was reported by 53.2% of athletes, heavy menstrual flow by 30.8%, and moderate-to-severe dysmenorrhea by 46.8%. No statistically significant associations were identified between menstrual cycle regularity, flow intensity, or dysmenorrhea severity and overall injury history or specific injury categories (all $p > 0.05$). Neither the menstrual-predictors-only logistic regression model ($\chi^2_{(5)} = 1.37$, $p = 0.927$; Nagelkerke $R^2 = 0.007$) nor the adjusted model ($\chi^2_{(9)} = 6.22$, $p = 0.718$; Nagelkerke $R^2 = 0.033$) was statistically significant.

Conclusions: Menstrual cycle characteristics were not significantly associated with retrospective sports injury history in this multi-sport sample of female athletes. Nevertheless, the frequent reporting of menstrual disturbances and previous injuries highlights the importance of addressing both aspects of athlete health. Prospective studies incorporating validated menstrual assessments, standardized injury surveillance, and sport-specific analyses are needed to clarify potential associations.

Keywords: Menstrual cycle; Sports injuries; Female athletes; Dysmenorrhea; Menstrual irregularity.

Background

Sports injuries represent a substantial concern in competitive female athletes because of their potential consequences for physical health, training continuity, athletic performance, and long-term participation in sport [1]. Injury occurrence is multifactorial, reflecting interactions among athlete-related characteristics, sport-specific physical demands, and training and competition exposure [2]. Within this context, menstrual health has received increasing attention as a potentially relevant component of female athlete health. Cyclical fluctuations in ovarian hormones

have been hypothesized to influence musculoskeletal tissue properties and neuromuscular function; however, evidence linking these physiological changes to actual sports injury occurrence remains inconsistent [3, 4].

Research on menstrual health and sports injuries has generally followed two distinct approaches. The first investigates injury occurrence across menstrual cycle phases, whereas the second examines associations between broader menstrual characteristics or disturbances and injury history. These approaches address related but different questions and should not be considered interchangeable. For example, Ferrer et al. [5], in a four-season prospective study of elite female football players, reported no statistically significant difference in injury incidence between menstrual bleeding and non-bleeding periods, although injury burden was higher during bleeding. Such findings highlight the importance of distinguishing injury occurrence from injury severity and burden.

Recent cross-sectional investigations have also examined menstrual characteristics in relation to injury outcomes. Kirschbaum et al. [6] evaluated menstrual health and lower-limb injuries among 301 elite female team-sport athletes and reported heterogeneous associations across menstrual and injury-related variables, with no significant association between dysmenorrhea and injury occurrence. Similarly, Witkoś et al. [7] investigated menstrual cycle characteristics and retrospective injury history among amateur female football players. Together, these studies demonstrate the relevance of examining menstrual health beyond phase-specific hormonal fluctuations while highlighting differences in study populations, menstrual assessments, and injury definitions.

Menstrual health encompasses multiple dimensions, including cycle regularity, cycle length, bleeding duration, perceived menstrual flow intensity, and dysmenorrhea [8, 9, 10]. These

characteristics may provide valuable information about athletes' reproductive health and symptom burden, although their presence or severity does not necessarily indicate increased injury susceptibility. Moreover, differences in sport-specific physical demands, training exposure, and injury mechanisms may complicate the interpretation of associations in heterogeneous athletic populations. A rapid review also documented substantial variation in the prevalence of menstrual disorders across sports disciplines [11].

Evidence linking menstrual cycle characteristics to sports injury history remains inconsistent. Studies differ in the menstrual characteristics assessed, injury definitions, and sporting populations, making it difficult to determine whether findings extend across injury categories and sports disciplines. A scoping review identified limited research among female athletes in low- and middle-income countries and highlighted the need for more longitudinal studies and standardized assessments [12].

This cross-sectional study therefore examined the associations of cycle regularity, cycle length, bleeding duration, perceived menstrual flow intensity, and dysmenorrhea severity with sports injury history among competitive female athletes from multiple sports disciplines. Overall injury history was the primary outcome, with secondary analyses addressing lower-limb, anterior cruciate ligament, muscle, overuse, and acute injuries.

Methods

Study Design and Setting

This cross-sectional observational study was conducted between 1 March and 30 July 2025 in Peshawar, Khyber Pakhtunkhwa, Pakistan. Participants were recruited from sports clubs and teams affiliated with the Khyber Pakhtunkhwa Sports Directorate, as well as university and college sports

programs. The study investigated associations between menstrual cycle characteristics and sports injury history among competitive female athletes. It was reported with reference to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Participants and Eligibility Criteria

Eligible participants were female athletes aged 18–30 years who competed at the elite or sub-elite level in one of nine sports disciplines: volleyball, hockey, martial arts, badminton, football, athletics, handball, cricket, or basketball. Elite and sub-elite status was defined as having participated in national-level and provincial-level games, respectively. Additional eligibility criteria were a menstrual history of at least 12 months and participation in training or competition during the previous competitive season. Eligibility was verified by a researcher-administered screening checklist before enrolment.

Athletes were excluded if they were pregnant, had used hormonal contraceptives or other exogenous hormonal therapies within the preceding six months, or had a known endocrine disorder affecting menstrual function, such as polycystic ovary syndrome or thyroid disease. Athletes who did not provide informed consent were also excluded.

Sampling and Sample Size

A convenience sample of competitive female athletes was recruited from nine sports disciplines. All eligible athletes who were available and consented during the recruitment period (1 March to 30 July 2025) were enrolled. No target number was set in advance, and no a priori sample size calculation was performed. Of 312 athletes approached, 38 were not eligible and 24 declined to take part, leaving 250 enrolled (80.1% of those approached and 91.2% of the 274 eligible athletes). All enrolled athletes were included in the analysis, and no analysed variable had missing data.

To indicate what the sample can and cannot detect, post hoc precision and sensitivity were calculated. With N = 250, the 95% confidence interval for the overall injury prevalence of 53.2% was approximately ±6.2 percentage points. At $\alpha = .05$ and 80% power, the chi-square tests could detect effects of about $w = 0.18$ (2×2 tables), 0.20 (3×2 tables), and 0.21 (4×2 tables), that is, small-to-medium associations; smaller associations cannot be ruled out. In the logistic regression models, the smaller outcome group (no injury, n = 117) provided about 13 events per predictor in the full nine-predictor model, above the commonly cited minimum of 10 [13]. Only 13 athletes had an anterior cruciate ligament (ACL) injury, so the ACL analyses are underpowered and interpreted descriptively.

Data Collection and Study Measures

Data were collected between March and July 2025 from eligible female athletes affiliated with the Khyber Pakhtunkhwa Sports Directorate and university or college sports programs in Peshawar. Following permission from the relevant sports authorities and coaches, eligible athletes were invited to participate. The study objectives and procedures were explained, and written informed consent was obtained before data collection.

The principal investigator and trained research assistants administered a structured questionnaire face to face, in English or Urdu, in a quiet setting before or after scheduled training sessions. The questionnaire (Appendix A) was researcher-developed with reference to the published literature on menstrual health in female athletes and to the recording principles of the International Olympic Committee (IOC) consensus statement on injury and illness surveillance in sport [14]. It comprised three sections: demographic and training characteristics, menstrual cycle characteristics, and sports injury history. Before data collection, three experts in sports sciences and women's health reviewed its relevance and clarity, and it was refined accordingly. This provides content (face) validity

evidence only: no pilot study or formal psychometric testing (test–retest agreement, internal consistency, or criterion validity) was undertaken. Most items are single-item self-reports, for which internal-consistency statistics are not applicable.

Height and body weight were measured using standardized procedures to calculate body mass index (BMI). Completed questionnaires were reviewed for completeness and consistency, and participants were asked to clarify missing or inconsistent responses. All data were anonymized and coded before statistical analysis.

Menstrual Cycle Characteristics

Five menstrual cycle characteristics were assessed by self-report without hormonal verification: cycle regularity, cycle length, bleeding duration, perceived flow intensity, and dysmenorrhea severity. Cycle regularity was classified as regular or irregular based on each participant's self-assessment, without applying a predefined clinical criterion for irregularity. Cycle length was recorded as the average number of days between the first days of consecutive menstrual periods, and bleeding duration as the average number of bleeding days per cycle. Perceived flow intensity was categorized as light, moderate, or heavy according to each participant's subjective assessment.

Dysmenorrhea severity was assessed using a 10-cm horizontal visual analogue scale (VAS), anchored by "no pain" (0) and "worst imaginable pain" (10) [15]. Participants marked their worst menstrual pain during a typical period over the preceding three months. The distance from the left endpoint to the mark was measured in centimetres and rounded to the nearest whole number. Scores were categorized as no pain (0), mild (1–3), moderate (4–7), or severe (8–10) [16, 17, 18]. The VAS form is provided in Appendix B.

Sports Injury Assessment

Sports injury history was assessed retrospectively for the 12 months preceding the survey. Using the IOC time-loss framework as a reference [14], the study applied an operational definition of injury as any sport-related musculoskeletal complaint sustained during training or competition that prevented full participation in sport for at least 3 days. For each injury, athletes reported the anatomical location, injury type, mode of onset, and number of days missed from sport. Overall injury history was coded as the presence or absence of at least one injury meeting this definition.

Reported injuries were confirmed through medical records, including physician or radiology reports, hospital discharge summaries, or sports-medicine clinic records. Participants provided written permission for these records to be reviewed. When medical records and participants' accounts differed, the records were used to determine injury location and type. Time loss was obtained from the records when a rest or return-to-play period was documented; otherwise, participants' recalled time loss was used. ACL injuries required confirmation by an MRI report or a diagnosis from an orthopaedic or sports-medicine physician.

Injuries were classified by anatomical location, tissue type, and mode of onset. Lower-limb injuries involved the hip, thigh, knee, lower leg, ankle, or foot. ACL injuries were defined as tears or ruptures of the anterior cruciate ligament and were analysed as a subset of lower-limb injuries. Muscle injuries included strains, tears, or ruptures. Acute injuries had a sudden onset associated with a specific event, whereas overuse injuries developed gradually without a single identifiable event. These categories were not mutually exclusive, as they represented different dimensions of injury and athletes could report more than one injury. Injuries with an unspecified or unclassifiable mode of onset were not assigned to either the acute or overuse category.

Injury severity was classified according to time lost from regular sports participation as minimal (3 days), mild (4–7 days), moderate (8–28 days), or severe (>28 days). These categories were

adapted from Fuller et al. [19] to reflect the study's minimum time-loss threshold of 3 days. Severity was reported only for injured athletes (n = 133). For athletes reporting multiple injuries, severity was based on the injury associated with the greatest time loss. All injury information was collected retrospectively rather than through prospective surveillance.

Demographic and Training Characteristics

Age (years), playing experience (years), and weekly training duration (hours/week) were collected by questionnaire. Body height and weight were measured, and BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2).

Statistical Analysis

Descriptive statistics (mean, standard deviation, frequencies, and percentages) described the sample, menstrual characteristics, and injury profile. Each association between a menstrual characteristic (cycle regularity, flow intensity, dysmenorrhea severity) and each injury outcome (overall, lower-limb, ACL, muscle, overuse, acute) was tested with Pearson's chi-square test of independence, without continuity correction, and Cramér's V was reported as the effect size. For comparisons with sparse expected cell counts, Monte Carlo p-values based on 20,000 resamples were reported; otherwise, asymptotic p-values were used.

Binary logistic regression was used to examine whether the five menstrual characteristics together were associated with overall injury (0 = no injury, 1 = injury; Model 1), and whether this held after adjustment for age, BMI, playing experience, and weekly training hours (Model 2). Flow intensity and dysmenorrhea severity were entered as ordinal scores. Model fit was evaluated with the likelihood-ratio chi-square, Cox & Snell, Nagelkerke, and McFadden R^2, and classification accuracy. Flow intensity and dysmenorrhea severity were coded as ordinal scores, assuming an

equal change in log odds between successive categories. This assumption was not formally assessed and is acknowledged as a limitation (see Strengths and Limitations).

Eighteen unadjusted chi-square tests were performed (three menstrual characteristics × six injury outcomes). None was significant at $p < .05$ even before correction for multiplicity, so no adjustment was applied, and no single test should be interpreted apart from the overall pattern of results. All tests were two-sided with $\alpha = .05$. Analyses were performed in Python 3 using pandas, NumPy, and SciPy; logistic models were fitted by maximum likelihood.

Ethical Considerations

The study was approved by the Institutional Ethics Review Committee (IERC) of Sarhad University of Science and Information Technology, Peshawar, Pakistan (approval number SUIT/ethics/219; approved on 7 February 2025, before the start of data collection). Written informed consent was obtained from all participants before data collection, including separate permission to consult their medical records. Participants were informed about the study objectives and procedures, the voluntary nature of participation, their right to withdraw at any time without consequences, and the confidentiality of their personal and menstrual health information. All data were anonymized, and the study was conducted in accordance with the principles of the Declaration of Helsinki.

Results

A total of 312 athletes were initially approached, of whom 38 did not meet the eligibility criteria and 24 declined participation. Consequently, 250 competitive female athletes representing nine sports disciplines were enrolled and included in the final analyses, accounting for 80.1% of all athletes approached and 91.2% of those eligible (n = 274). No participants were excluded after

enrolment, and complete data were available for all variables examined. The participants had a mean age of 24.19 ± 3.78 years and a mean weekly training duration of 12.78 ± 4.44 hours (Table 1).

Table 1. Demographic, training, and sport characteristics of participants (n = 250)

Demographic and training characteristics	n (%) or M ± SD (Min–Max)
Age (years)	24.19 ± 3.78 (18–30)
BMI (kg/m²)	22.90 ± 2.92 (18.0–27.9)
Playing experience (years)	5.85 ± 2.77 (1–10)
Training duration (hours/week)	12.78 ± 4.44 (6–20)
Sport discipline	n (%) or M ± SD (Min–Max)
Volleyball	36 (14.4)
Hockey	35 (14.0)
Martial arts	32 (12.8)
Badminton	31 (12.4)
Football	29 (11.6)
Athletics	22 (8.8)
Handball	22 (8.8)
Cricket	22 (8.8)
Basketball	21 (8.4)

Notes: M = mean; SD = standard deviation; BMI = body mass index.

Menstrual Cycle Characteristics

Among the 250 athletes, 133 (53.2%) reported irregular menstrual cycles. The mean cycle length was 30.51 ± 8.51 days, and the mean bleeding duration was 5.00 ± 1.45 days. Flow intensity and dysmenorrhea severity are shown in Table 2.

Table 2. Menstrual cycle characteristics of the participants (n = 250)

Menstrual cycle regularity	**n (%) or M ± SD (Min–Max)**
Regular	117 (46.8)
Irregular	133 (53.2)
Cycle length (days)	30.51 ± 8.51 (18–45)
Bleeding duration (days)	5.00 ± 1.45 (3–7)
Menstrual flow intensity	**n (%) or M ± SD (Min–Max)**
Light	50 (20.0)
Moderate	123 (49.2)
Heavy	77 (30.8)
Dysmenorrhea severity (VAS)	**n (%) or M ± SD (Min–Max)**
No pain	69 (27.6)
Mild	64 (25.6)
Moderate	51 (20.4)
Severe	66 (26.4)

Notes: M = mean; SD = standard deviation; VAS = visual analogue scale (10 cm).

Sports Injury History

Overall, 133 athletes (53.2%) had at least one medically confirmed sports injury during the preceding 12 months, and 95 (38.0%) had a lower-limb injury. The distribution of injury types and severity is shown in Table 3.

Table 3. Sports injury history, injury types, and severity

Overall injury history (N = 250)	**n (%)**
No injury	117 (46.8)
At least one injury	133 (53.2)
Injury types (N = 250)	n (%)
Lower-limb injury	95 (38.0)
ACL injury	13 (5.2)
Muscle injury	48 (19.2)
Overuse injury	49 (19.6)
Acute injury	59 (23.6)
Injury severity, worst injury (n = 133)	n (%)
Minimal (3 days)	41 (30.8)
Mild (4–7 days)	53 (39.8)
Moderate (8–28 days)	27 (20.3)
Severe (> 28 days)	12 (9.0)

Notes: Injury types are percentages of the total sample (N = 250) and overlap: 25 athletes had both an acute and an overuse injury, and 50 of the 133 injured athletes had neither (mode of onset not specified or not fitting either category). Severity percentages are among injured athletes (n = 133). ACL = anterior cruciate ligament. Percentages may not total 100% because of rounding.

Associations Between Menstrual Characteristics and Injury

No statistically significant association was observed between cycle regularity, flow intensity, or dysmenorrhea severity and overall injury history (Table 4).

Table 4. Associations Between Menstrual Cycle Characteristics and Overall Injury History

	No injury, n (%)	Injury, n (%)	χ^2	df	p	Cramér's V
Cycle regularity						
Regular	52 (44.4)	65 (55.6)	0.49	1	.484	.044
Irregular	65 (48.9)	68 (51.1)				
Menstrual flow intensity						
Light	24 (48.0)	26 (52.0)				
Moderate	55 (44.7)	68 (55.3)	0.44	2	.801	.042
Heavy	38 (49.4)	39 (50.6)				
Dysmenorrhea severity						
No pain	29 (42.0)	40 (58.0)				
Mild	32 (50.0)	32 (50.0)	1.00	3	.802	.063
Moderate	25 (49.0)	26 (51.0)				
Severe	31 (47.0)	35 (53.0)				

Notes: Values are n (row %). Pearson's chi-square tests without continuity correction.

No statistically significant associations were observed between any menstrual characteristic and any of the five injury categories (all $p > .05$; Table 5). Descriptively, lower-limb injury was reported by 44.9% of athletes without dysmenorrhea compared with 28.1% of those with mild dysmenorrhea ($\chi^2_{(3)} = 4.14$, $p = .247$). ACL injury was reported by 0.0%, 4.7%, 9.8%, and 7.6% of athletes with no, mild, moderate, and severe dysmenorrhea, respectively ($\chi^2_{(3)} = 6.77$, $p = .080$; Monte Carlo $p = .072$). Acute injury was reported by 18.8% of athletes without dysmenorrhea and 31.4% of those with moderate dysmenorrhea ($\chi^2_{(3)} = 3.90$, $p = .272$). These differences were not statistically significant and should not be read as evidence of association; the ACL comparison involved sparse cells (only 13 cases). Detailed cross-tabulations are in Supplementary Table S1.

Table 5. Associations Between Menstrual Cycle Characteristics and Specific Injury Types

Injury type	Menstrual characteristic	χ^2	df	p	Cramér's V
Lower-limb	Cycle regularity	0.44	1	.507	.042
	Flow intensity	0.42	2	.809	.041
	Dysmenorrhea severity	4.14	3	.247	.129
ACL	Cycle regularity	0.00	1	.962	.003
	Flow intensity	0.21	2	.937[a]	.029
	Dysmenorrhea severity	6.77	3	.072[a]	.165
Muscle	Cycle regularity	0.24	1	.621	.031
	Flow intensity	1.75	2	.417	.084
	Dysmenorrhea severity	0.27	3	.966	.033
Overuse	Cycle regularity	0.00	1	.983	.001
	Flow intensity	1.22	2	.542	.070
	Dysmenorrhea severity	1.16	3	.762	.068
Acute	Cycle regularity	0.23	1	.630	.030
	Flow intensity	1.86	2	.394	.086
	Dysmenorrhea severity	3.90	3	.272	.125

Notes: χ^2 = Pearson's chi-square statistic; df = degrees of freedom; ACL = anterior cruciate ligament. Tests were performed without continuity correction. [a]Monte Carlo p-values based on 20,000 resamples were used for comparisons with sparse expected cell counts; all other p-values are asymptotic. Effect sizes are expressed as Cramér's V. Injury categories were not mutually exclusive.

The logistic regression model including the five menstrual characteristics was not statistically significant ($\chi^2(5) = 1.37$, $p = .927$; Nagelkerke $R^2 = .007$). After adjustment for age, BMI, playing experience, and weekly training duration, the model remained non-significant ($\chi^2_{(9)} = 6.22$, $p = .718$; Nagelkerke $R^2 = .033$). No individual predictor was statistically significant in either model. Estimates and model fit statistics are presented in Table 6, with full regression coefficients provided in Supplementary Table S2.

Table 6. Logistic Regression Models for Overall Injury History

Predictor	Model 1 OR (95% CI)	p	Model 2 aOR (95% CI)	p
Cycle regularity (irregular vs. regular)	0.819 (0.494–1.359)	.440	0.817 (0.488–1.368)	.443
Flow intensity (ordinal)	0.951 (0.665–1.359)	.782	0.920 (0.640–1.322)	.652
Dysmenorrhea severity (ordinal)	0.939 (0.755–1.168)	.572	0.926 (0.742–1.154)	.493
Bleeding duration (days)	1.060 (0.891–1.260)	.511	1.055 (0.885–1.257)	.553
Cycle length (days)	1.005 (0.976–1.035)	.738	1.004 (0.975–1.035)	.782
Age (years)	—	—	0.967 (0.904–1.034)	.330
BMI (kg/m²)	—	—	1.021 (0.936–1.114)	.644
Playing experience (years)	—	—	0.966 (0.880–1.059)	.458
Training duration (hours/week)	—	—	0.949 (0.895–1.005)	.074
Model χ^2 (df)	1.37 (5)	.927	6.22 (9)	.718
Nagelkerke R^2	.007	—	.033	—
Classification accuracy (%)	51.6	—	58.0	—

Notes: Model 1 included cycle regularity, flow intensity, dysmenorrhea severity, bleeding duration, and cycle length simultaneously. Model 2 additionally included age, BMI, playing experience, and weekly training duration. Injury history was coded as 0 = no injury and 1 = injury. OR = odds ratio; aOR = adjusted odds ratio; CI = confidence interval; BMI = body mass index. For ordinal predictors, ORs represent a one-category increase; for continuous predictors, ORs represent a one-unit increase.

Discussion

This cross-sectional study examined the associations between menstrual cycle characteristics and sports injury history among competitive female athletes from nine sports disciplines. More than half of the participants had at least one medically confirmed sports injury during the preceding 12 months (53.2%), while menstrual irregularity (53.2%) and moderate-to-severe dysmenorrhea (46.8%) were also frequently reported. However, no statistically significant associations were identified between menstrual cycle regularity, flow intensity, or dysmenorrhea severity and overall injury history or any of the five injury categories examined. Similarly, neither the logistic regression model including only menstrual cycle characteristics nor the model additionally

adjusted for age, BMI, playing experience, and weekly training duration was statistically significant.

These findings indicate that the menstrual characteristics assessed in this study were not significantly associated with retrospective sports injury history. Nevertheless, the absence of statistically significant associations should not be interpreted as evidence that menstrual physiology has no influence on sports injuries, particularly because menstrual cycle phases and injury timing were not prospectively assessed. With 250 athletes the study could detect only small-to-medium effects ($w \approx 0.18–0.21$), so smaller associations cannot be excluded.

The relationship between menstrual health and sports injuries in female athletes remains a subject of considerable debate, with previous studies reporting inconsistent findings. MacMillan et al. [3], in a scoping review, highlighted substantial methodological heterogeneity in menstrual cycle assessment, injury definitions, and study populations, limiting the comparability of findings across investigations. Similarly, Martínez-Fortuny et al. [20] emphasized the uncertainty surrounding menstrual cycle-related injury patterns. These observations provide an important context for interpreting the present findings, in which menstrual cycle regularity, flow intensity, and dysmenorrhea severity were not significantly associated with injury history.

Studies examining menstrual dysfunction and retrospective injury outcomes have produced mixed results. Baumgartner et al. [21] investigated menstrual health and injuries among Swiss elite athletes and reported associations involving secondary amenorrhea, training exposure, and injury history. Witkoś et al. [22] also examined menstrual disturbances and sports injuries among competitive swimmers, suggesting that menstrual health characteristics may be relevant to injury-related outcomes in specific athletic populations. In contrast, the present study identified no significant associations between menstrual irregularity and either overall injury history or the five

injury categories examined. Differences in the definitions of menstrual dysfunction, sport-specific physical demands, and injury assessment methods may partly explain these discrepancies.

More recently, Kirschbaum et al. [6] examined menstrual characteristics and lower-limb injury history among 301 elite female athletes participating in five team sports. Although menstrual dysfunction was associated with a lower prevalence of anterior cruciate ligament (ACL) injuries, dysmenorrhea and premenstrual syndrome were not significantly associated with injury outcomes. The absence of a significant association involving dysmenorrhea is consistent with the present findings. However, the direction of the association involving menstrual dysfunction highlights the complexity of interpreting menstrual health indicators as potential injury-related factors. Importantly, the present study included only 13 athletes with ACL injuries, limiting the precision of conclusions regarding this specific injury category. Dos'Santos et al. [23] likewise reported mixed findings and very low-certainty evidence concerning phase-related changes in neuromuscular and biomechanical ACL injury-risk surrogates. Such surrogate outcomes should be distinguished from clinically confirmed ACL injuries.

Witkoś et al. [7] investigated menstrual cycle characteristics and retrospective injury history among 118 adult amateur female football players using selected items from the Low Energy Availability in Females Questionnaire. Their findings further demonstrate the relevance of examining menstrual health and injury history within athletic populations. Nevertheless, differences in sporting level, sample composition, menstrual assessment, and analytical approach limit direct comparisons. The present study extends this line of investigation by examining several menstrual characteristics across nine sporting disciplines, although sport-specific associations were not evaluated.

Prospective studies examining injury occurrence across menstrual cycle phases provide a different perspective. Barlow et al. [24] monitored 26 professional female football players over three competitive seasons and reported higher muscle injury incidence during the early luteal and premenstrual phases compared with menstruation. Similarly, Ferrer et al. [5], in a four-season observational study of elite female football players, found that injury incidence did not differ significantly between menstrual bleeding and non-bleeding periods, although injury burden was greater during bleeding. These findings suggest that menstrual-related patterns may differ according to the injury outcome considered, including incidence, type, and severity. Fort-Vanmeerhaeghe et al. [25] also prospectively monitored 59 elite adolescent team-sport athletes and reported higher injury incidence during the luteal phases. These investigations assessed injury timing prospectively, whereas the present study relied on retrospective injury history without determining the menstrual phase in which injuries occurred.

Evidence from systematic reviews further illustrates the uncertainty surrounding phase-specific injury associations. Guthardt et al. [26], in a systematic review and meta-analysis involving female team-sport athletes, found no statistically significant difference in muscle injury risk between the luteal and follicular phases. The authors also identified very low certainty of evidence, emphasizing the limitations of the available research. Therefore, the absence of significant associations in the present study should not be interpreted as contradicting all previous reports of menstrual phase-related injury patterns. Rather, these investigations address related but distinct research questions.

Beyond injury occurrence, menstrual symptoms represent an important aspect of athlete health. Hayward et al. [27] reported that professional female rugby players perceived menstrual-related effects on athletic performance and injury susceptibility, while Taim et al. [28] documented the

prevalence and burden of menstrual disorders and related symptoms among female athletes. In the present study, 46.8% of participants reported moderate-to-severe dysmenorrhea, despite the absence of a statistically significant association between dysmenorrhea severity and injury history. This distinction is important because menstrual symptoms may warrant clinical attention even when they are not associated with the injury outcomes examined. Abbas et al. [29] reported an association between training exposure and menstrual dysfunction, whereas Syed et al. [30] identified disordered-eating risk among young elite female athletes. These studies address broader athlete-health concerns rather than establishing a relationship between menstrual characteristics and injury. Energy availability and eating behaviours were not assessed in the present study, limiting comparison with this literature.

Collectively, the available evidence indicates that associations between menstrual health and sports injuries vary according to the menstrual characteristics assessed, injury outcomes, sporting populations, and study designs. The present findings contribute evidence from a multi-sport sample of female athletes but do not establish the absence of menstrual cycle-related injury mechanisms. Future prospective investigations incorporating validated menstrual assessments, standardized injury surveillance, accurate injury timing, and sport-specific analyses are needed to clarify these relationships.

Practical Implications

The findings of this study highlight the importance of considering menstrual health and sports injury history as distinct but relevant components of female athlete health monitoring. Although menstrual irregularity and dysmenorrhea were frequently reported, neither was significantly associated with retrospective injury history. Therefore, the present findings do not support using

these menstrual characteristics alone to identify athletes at increased injury risk or to guide injury-prevention strategies.

Nevertheless, routine assessment of menstrual cycle characteristics and symptoms may help coaches and healthcare professionals recognize athletes who could benefit from further clinical evaluation or individualized support. In resource-limited sporting environments, accessible menstrual health education, appropriate referral pathways, and standardized injury surveillance may contribute to more comprehensive athlete healthcare. These approaches should complement, rather than replace, established injury-prevention practices.

Strengths and Limitations

The study has several strengths. The inclusion of 250 competitive female athletes from nine sports disciplines provides evidence from a geographically underrepresented athletic population. Injuries were confirmed through medical records and classified using IOC-based definitions with an explicit time-loss threshold, and multiple menstrual characteristics were assessed alongside overall and specific injury categories.

Several limitations should also be acknowledged. First, the cross-sectional design precludes causal inference, and the retrospective assessment of injury history and self-reported menstrual characteristics may introduce recall and reporting biases. Menstrual cycle phases were neither prospectively monitored nor hormonally verified, preventing the examination of phase-specific injury patterns. Second, convenience sampling from a single geographical region limits generalizability, and sport-specific associations were not examined despite potential differences in training demands and injury mechanisms. Because injuries were counted when confirmed in

medical records, minor injuries managed without medical consultation may be under-represented, and time lost relied on athletes' recall when records gave no return-to-play date.

Third, although Monte Carlo exact tests were used to address sparse cells in the ACL analyses, the small number of ACL injuries (n = 13) limited the precision of comparisons and the ability to detect associations. Flow intensity and dysmenorrhea severity were entered as ordinal predictors in the logistic regression models, assuming an equal change in log odds between successive categories; this assumption was not formally assessed. Fourth, the menstrual and injury questionnaires were researcher-developed and supported only by expert content review; their reliability and criterion validity were not formally evaluated. Finally, the sample was one of convenience without an a priori sample size calculation, so small associations may have gone undetected.

Collectively, these limitations suggest that the absence of statistically significant associations should be interpreted cautiously rather than as definitive evidence of no relationship between menstrual characteristics and sports injuries.

Conclusions

This cross-sectional study found no statistically significant associations between menstrual cycle characteristics and sports injury history among competitive female athletes from multiple sports disciplines. Nevertheless, the frequent reporting of menstrual irregularity, dysmenorrhea, and previous sports injuries highlights the importance of addressing menstrual health and injury prevention as complementary aspects of female athlete care. These findings should be interpreted in light of the retrospective design and the absence of prospective menstrual cycle monitoring. Future longitudinal studies incorporating validated menstrual assessments, standardized injury

surveillance, and sport-specific analyses are needed to clarify potential associations between menstrual health and sports injuries.

List of abbreviations: ACL: Anterior cruciate ligament; aOR: Adjusted odds ratio; BMI: Body mass index; CI: Confidence interval; df: Degrees of freedom; IOC: International Olympic Committee; MRI: Magnetic resonance imaging; OR: Odds ratio; SD: Standard deviation; STROBE: Strengthening the Reporting of Observational Studies in Epidemiology; VAS: Visual analogue scale.

Additional files

Appendix A. Questionnaire. The researcher-developed questionnaire (eligibility screening, informed consent, demographic and training characteristics, menstrual cycle characteristics, sports injury history, and medical-record confirmation) is supplied as a separate document: Appendix A.

Appendix B. Visual analogue scale (VAS) for menstrual pain. A 10-cm horizontal line anchored "no pain" (0) and "worst imaginable pain" (10), with the instruction to mark the worst pain of a typical period over the past three months. The form must be printed at 100% scale so that the line measures exactly 10 cm, and the researcher records the distance in centimeters, the rounded score, and the category.

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During manuscript preparation, the authors used ChatGPT (OpenAI) to improve language and grammar. All AI-assisted text was reviewed and edited by the authors, who take full responsibility for the final content of the manuscript.

Authors' contributions

GM and SM conceptualized the study. GM, SM, CG, BŞ, ŞD, SU, and SÖ designed the study and planned the methodology. GM and SM coordinated the research, obtained ethics approval, and collected the data. GM, SM, CG, and SU performed the statistical analyses. CG, BŞ, ŞD, and AD managed and organized the data. GM, SM, BŞ, and CG drafted the manuscript. All authors critically reviewed and edited the manuscript and approved the final version.

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Data availability

The datasets generated and analysed in this study are available upon reasonable request from the corresponding author.

Declarations

Ethics approval and consent to participate

The study was approved by the Institutional Ethics Review Committee of Sarhad University of Science and Information Technology, Peshawar, Pakistan (approval number: SUIT/ethics/219; 7 February 2025). Written informed consent was obtained from all participants, including permission to review their medical records. The study was conducted in accordance with the Declaration of Helsinki.

Clinical trial number: not applicable.

Consent for publication

Not applicable.

Competing interests:

The authors declare that they have no competing interests.

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Supplementary Files

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- SupplementaryMaterials.docx