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Original Article

Analysis of injury incidence in athletes throughout the phases of the menstrual cycle

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Abstract
The incidence of injuries in female athletes may be influenced by hormonal fluctuations during the different phases of the menstrual cycle (MC). Therefore, the aim of this study was to investigate the occurrence of injuries among athletes from various sports disciplines across the phases of the MC. This is a cross-sectional, exploratory, and retrospective study, conducted through an electronic questionnaire distributed to university sports associations in Brazil. Of the 120 associations invited, 14 responded, totaling 100 athletes. The questionnaire was divided into four sections (sociodemographic data, training history, injuries, and gynecological conditions), allowing for the correlation of injuries with the phases of the MC. Statistical analysis was performed using Pearson's chi-square test (χ^2), with significance set at $p < 0.05$. The athletes had a mean age of 21.80 (±2.84) years, with 53% reporting at least one injury in the past 12 months. Injured athletes were younger (21.60 ± 2.85 years; $p < 0.001$), had less training experience (15.70 ± 13.20 months; $p < 0.001$), greater weekly training volume (2.98 ± 1.42 days; $p < 0.001$), and more annual competitions (3.92 ± 5.12; $p < 0.001$). Injuries were more frequent during the late follicular phase (45.3%; $p < 0.001$) and the luteal phase (34%; $p < 0.001$), predominantly joint-related and non-contact. No significant differences were found between contraceptive users and non-users ($p > 0.05$). It is concluded that the late follicular and luteal phases are associated with a higher risk of non-contact joint injuries. Longitudinal studies are recommended to further clarify how MC phases influence injury incidence in athletes.
Keywords. Hormonal fluctuations, Non-contact injuries, Female athletes.

Introduction

The menstrual cycle (MC) is a physiological process that occurs during the reproductive years of women, characterized by a series of hormonal and anatomical changes that prepare the body for a possible pregnancy. A typical MC lasts an average of 28 days, although it may range from 21 to 35 days, and is divided into four main phases: early follicular, late follicular, ovulatory, and luteal (Oliveira et al., 2009; Lago Fuentes et al., 2021; Kissow et al., 2022). Among the physiological changes associated with the MC, hormonal fluctuations, mainly in estrogen and progesterone levels, influence psychophysical conditions such as mood, energy levels, and physical performance (Pisapia et al., 2019; Senatore et al., 2019; McLaughlin, 2024; Villaseca Vicuña et al., 2024).

These psychophysical variations may lead to changes in performance and a higher risk of injury throughout the MC, particularly joint injuries, due to joint instability influenced by variations in estrogen, progesterone, and relaxin levels during specific phases (Lopes et al., 2013; Fracaro et al., 2018; César, Pereira and Serrão, 2021; Frizziero et al., 2023; Dehghan et al., 2024). Understanding the behavior of strength, flexibility, and joint stability throughout the MC is essential for designing more effective training programs aimed at performance and injury prevention (Pereira et al., 2024). In addition, monitoring injury incidence is crucial for effective athlete periodization.

Although previous studies have explored the influence of hormonal fluctuations on physical performance, there is still limited evidence regarding the association between specific phases of the MC and injury occurrence in athletes across different sports. This gap in the literature justifies the need for further investigation. Identifying the phases of the MC in which female athletes are more vulnerable to injury can contribute to the development of personalized strategies for injury prevention, which are still lacking in current practice.

According to Kendall et al. (2008), joint instability increases the risk of sprains and connective tissue injuries. Preventive training focused on muscle strengthening can improve the function of dynamic stabilizers and reduce the likelihood of joint injuries (Kendall et al., 2008; Pereira et al., 2024).

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In this context, this study was designed to provide additional insights into how injury incidence may be affected by the phases of the MC, and to offer data that could support evidence-based decisions in sports training and periodization for female athletes. Considering the hormonal changes that occur throughout the MC, the increased vulnerability to joint injuries and their potential impact on athletic performance, as well as the importance of preventive training strategies, this study aimed to analyze the incidence of injuries in athletes from different sports during the various phases of the MC. To do this, a retrospective analysis was carried out using data collected from a structured questionnaire applied to female university athletes from different regions of Brazil, allowing us to correlate reported injuries with MC phases. The objective is to identify the periods in which athletes are most vulnerable and to characterize the injuries that occur during these phases, supporting training optimization and injury prevention strategies.

Material & Methods

Study type and population

This is a cross-sectional, exploratory, and retrospective study (Thomas, Nelson and Silverman, 2012), conducted electronically via a form from December 11, 2023, to April 1, 2024. The study was approved by the Human Research Ethics Committee of the University of Pernambuco (HUOC/UPE), with approval number 3,696,219, adhering to all ethical guidelines established by Resolution 466/12, which regulates research involving human subjects. To participate in the study, the sample consisted of women over 18 years of age, who had been university athletes for at least 12 months, regularly attending training sessions at least twice a week, whether or not using contraceptives, and reported having a regular 28-day MC. Athletes were excluded if they were unsure about having a regular 28-day MC, did not menstruate, were not registered with the athletic associations (or equivalent) of the universities, or were uncertain about the occurrence or date of injuries in the past 12 months.

Study design

Before the sample selection, a sample size calculation was conducted for the study, which considered a minimum difference between groups of 1.0 (effect size) and an estimated variability with a standard deviation of 2.7, based on literature data. The test power was set at 0.70, providing sensitivity to detect significant differences. Using SigmaPlot software, version 14, the required sample size was calculated to be 91 athletes. To ensure the robustness of the study, a sample loss margin of 5% was included, resulting in the selection of 100 athletes, thus maintaining the necessary representativeness even in the face of possible losses.

The study was conducted through an electronic form (Google Forms) distributed to university athletes. To reach the participants, a survey was conducted on social media (Instagram and Facebook) of athletic associations (or equivalents) from public and private universities in Brazil. A total of 120 associations were mapped and invited to participate, but only 14 responded to the invitation. After establishing contact, the link to the form was sent along with a brief explanatory text, which included the inclusion and exclusion criteria, the study objectives, and a detailed explanation of the questionnaire. The link was then shared with the athletes by the associations themselves. The sample selection was finalized upon obtaining 100 responses, which ensured the pre-calculated representativeness.

The electronic form consisted of four sections. In the first section, upon accessing the link, athletes were directed to the Informed Consent Form (ICF), which provided all the information about the study, including inclusion criteria, objectives, risks, and benefits. Athletes who agreed to participate clicked the 'I agree to participate' icon and were directed to the next section, while those who did not agree clicked the 'I do not agree to participate' icon, which immediately ended the questionnaire. In the second section, athletes were asked about their sociodemographic conditions; in the third section, about their training history and injuries in the past 12 months; and in the fourth section, about their gynecological history (Masuda and Okada, 2023; Chang et al., 2024).

Collection Instruments

The form was created and made available via Google Forms, with each section (total of four) being independent, allowing participants to advance only after completing each section. In the first step, participants read and agreed to the ICF, as detailed earlier in the study design.

In the second and third sections, respectively, athletes answered questions about sociodemographic data, training history, injury recall, training volume and intensity, injuries occurring in the past 12 months, and details about these injuries (type, timing, and mechanism).

In the fourth section, athletes provided detailed information about their gynecological history (Masuda and Okada, 2023; Chang et al., 2024), menstrual flow pattern, interval between MC, use of contraceptives, as well as the dates of menarche and the last menstruation.

To correlate injuries with the MC phase, the cycle phase was determined based on the date of the last reported menstruation, with this date referred to as day 1. Injuries occurring between days 1 and 4 were categorized as early follicular phase, between days 5 and 12 as late follicular phase, between days 13 and 15 as ovulatory phase, and between days 16 and 28 as luteal phase (Jonge et al., 2019; ACOG, 2022).

Data analysis and processing

Statistical analysis was conducted using IBM SPSS Statistics for Windows, version 20.0 (Armonk, NY: IBM Corp). The Shapiro-Wilk test indicated that the data did not follow a normal distribution, justifying the use of non-parametric statistical methods. Descriptive analysis was employed to characterize the sample, presenting means and standard deviations. Pearson's χ^2 test was used to compare qualitative variables across the different phases of the MC (early follicular, late follicular, ovulatory, and luteal) and the occurrence of injuries in athletes. The significance level was set at $p < 0.05$.

Results

The sample, comprising 100 university athletes, included 20.0% participating in individual sports and 80.0% in team sports. The sample was divided into two groups: with injury (53 athletes) and without injury (47 athletes). Of the total, 83% reported having experienced injuries throughout their sports careers, with 53% of these injuries occurring in the past 12 months. Most injuries occurred during training (78.8%), with a predominance of joint injuries (40.0%) and non-contact injuries (59.0%).

Average age was 21.80 (± 2.84) years, with injured athletes being older ($\Delta = 1.8\%$; $p < 0.001$). Athletic careers averaged 16.30 (± 14.00) months, with a shorter duration for those who sustained injuries ($\Delta = 7.6\%$; $p < 0.001$). The athletes started their sports activities at an average age of 10.90 (± 5.15) years, with no significant difference between those who sustained injuries and those who did not ($p > 0.05$). Currently, they train an average of 2.94 (± 1.46) days per week, with a higher training volume among those who sustained injuries ($\Delta = 3.0\%$; $p < 0.001$). Participation in competitions averaged 3.51 (± 4.10) annually, with injured athletes taking part in more competitions ($\Delta = 22.4\%$; $p < 0.001$) (Table 1).

Table 1. Sample characterization (n = 100)

	Sample Mean±SD (n = 100)	**With injury Mean±SD (n = 53)**	**No injury Mean±SD (n = 47)**	**Δ (%) p**
Age (years)	21.80±2.84	21.60±2.85	22.00±2.85	**0.40 (1.8) <0.001***
Time as an athlete (months)	16.30±14.00	15.70±13.20	16.90±15.00	**1.2 (7.6) <0.001***
Sports start (Age years)	10.90±5.15	10.90±5.16	10.80±5.19	0.10 (0.9) 0.318
Training frequency (days)	2.94±1.46	2.98±1.42	2.89±1.51	**0.09 (3.0) <0.001***
Annual competitions (quantity)	3.51±4.10	3.92±5.12	3.04±2.45	**0.88 (22.4) <0.001***

N= Number, SD = Standard Deviation, **p*<0.001: Significant difference

Regarding the history of gynecological conditions, menarche was most frequently reported at ages 11, 12, and 13 (30.0%, 23.0%, and 22.0%, respectively), with 54.0% of the athletes reporting an average menstrual flow. The average age of menarche was 11.90 (± 1.43) years for athletes who sustained injuries and 12.00 (± 1.47) years for those who did not, with no significant differences between the groups ($p > 0.05$). Regarding contraceptive use, 58.0% of the athletes reported not using any method, with the majority of both injured and non-injured athletes reporting not using contraceptives (76.3% and 69.4%, respectively), with no significant differences between the groups ($p > 0.05$).

When correlating injuries with the phases of the MC (Table 2), it was observed that athletes in the late follicular and luteal phases had a significantly higher prevalence of injuries, with 45.3% ($p < 0.001$) and 34.0% ($p < 0.001$), respectively. In comparison, the early follicular phase had a prevalence of 11.3% ($p > 0.05$) and the ovulatory phase had a prevalence of 5.7% ($p > 0.05$). These results indicate that the late follicular and luteal phases are associated with a significantly higher risk of injury susceptibility.

Table 2. Description and comparison of menstrual cycle phases with injuries-

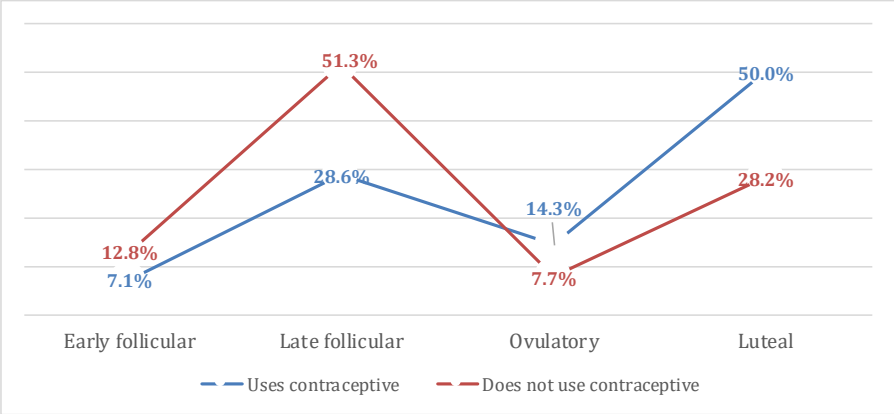
Phases	**Injured Athletes (n = 53)**	**Value p**	**χ^2**
Early follicular	11.3%	0.072	3.23
Late follicular	45.3%	**<0.001***	12.50
Ovulatory	5.7%	0.879	0.0231
Luteal	34.0%	**<0.001***	11.40

N= Number, **p*<0.001: Significant difference

Examining the characteristics of injuries during the phases with higher likelihood of occurrence revealed that, in the late follicular phase, most injuries were of joint origin (36.6%), occurred predominantly without physical contact (63.3%), and primarily affected athletes participating in team sports (62.1%). In the luteal phase, most injuries were also of joint origin (52.4%), occurred without physical contact (76.2%), and were more common among athletes participating in individual sports (54.9%).

When athletes who sustained injuries were divided into two groups—those who used contraceptive methods (n = 14; 26.4%) and those who did not (n = 39; 73.6%)—no significant differences in injury occurrence were found in any phase of the MC ($p > 0.05$). Among contraceptive users, the highest prevalence of injuries was observed in the luteal phase (50.0%), while among non-users, the highest prevalence occurred in the late follicular phase (51.3%) (Figure 1).

Figure 1. Description and comparison of menstrual cycle phases with injuries, separating athletes with and without contraceptive use



Discussion

The study found that most athletes (64.0%) experienced injuries during the last 12 months. The most vulnerable phases of the MC were the late follicular phase (45.3%; $p < 0.001$) and the luteal phase (34.0%; $p < 0.001$).

The physiology of the late follicular phase is characterized by elevated levels of estrogen and progesterone due to the hormonal fluctuations typical of the MC. The increase in these hormones can trigger a variety of symptoms in women, affecting connective tissues and muscle function, which in turn influences joint stability and muscle strength (Lopes et al., 2013; Fracaro et al., 2018; César, Pereira and Serrão, 2021; Frizziero et al., 2023). In connective tissues, elevated levels of estrogen and progesterone can impact their integrity due to their diverse actions. This occurs because these hormones increase collagen synthesis and the activity of enzymes such as matrix metalloproteinases, which degrade the extracellular matrix. This increase in tissue remodeling can result in greater ligament laxity and decreased tendon stiffness, contributing to reduced joint stability and increased susceptibility to joint injuries during this phase of the MC (César, Pereira and Serrão, 2021). Regarding muscle strength, elevated estrogen levels affect neuromuscular transmission and muscle excitation-contraction coupling, influencing muscle contraction efficiency. Conversely, increased progesterone may have a sedative effect on the central nervous system, reducing neural excitability and motor coordination Lopes et al., 2013; Fracaro et al., 2018; César, Pereira and Serrão, 2021; Frizziero et al., 2023).

In this study, the predominance of injuries during the late follicular phase was joint-related (36.6%), with most being non-contact injuries (63.3%). These findings suggest that hormonal fluctuations during this phase may have a direct relationship with increased susceptibility to joint injuries, due to reduced joint stabilization, both static (connective tissues) and dynamic (muscle strength and activation) (Kendall et al., 2008).

Supporting the data from this study, Lefevre et al. (2013) identified a higher prevalence of injuries during the late follicular phase, with a rate of 36.6% among 172 skiers evaluated. This phase also showed a significant incidence of knee injuries, with 33.7% of the injuries resulting in anterior cruciate ligament (ACL) tears. This specific injury (ACL tear) suggests a combination of joint instability during the late follicular phase with the specificity of skiing, where the diverse movements increase the posterior-anterior tibial force relative to the femur.

The results from Martin et al. (2021), who observed 113 football players, were similar to those found in this study. They also identified higher incidences of injuries during the late follicular phase (46.8%) and the luteal phase (35.4%), with most of these injuries being joint-related (36.0%). In the present study, the luteal phase had the second highest incidence of injuries (34.0%), with a prevalence of joint injuries (52.4%) and, predominantly, non-contact injuries (76.2%).

The luteal phase is characterized by a significant increase in progesterone levels, due to the release of the egg which forms the corpus luteum. This rise in progesterone, combined with estrogen as in the late follicular phase, further enhances joint instability, increasing susceptibility to joint injuries. This effect is exacerbated by the sedative impact of elevated progesterone on the central nervous system, influencing muscle contraction.

Moreover, elevated progesterone levels (higher than in the late follicular phase) during the luteal phase lead to increased water retention, causing joint edema that contributes to pain and restricted movement, thus heightening the risk of joint injuries, particularly non-contact injuries such as sprains (McLaughlin, 2024; Pinkerton, Vaughan, Kaunitz, 2024).

According to Dehghan, Soori, and Yusof (2024), who assessed 46 healthy women, the luteal phase, with high progesterone levels, also showed increased concentrations of relaxin, which further exacerbates joint instability due to its effect on connective tissue laxity. The study divided the sample into athletes (n = 24) and non-athletes (n = 22), finding that athletes had less joint instability during this phase compared to non-athletes. These findings were attributed to the greater muscle strength of athletes, which supports dynamic stabilization. Physical exercise, particularly strength training, may act as a protective agent against susceptibility to injuries during this phase of the MC.

Supporting the hypothesis that muscle strengthening exercises can act as protective agents against susceptibility to injuries during vulnerable phases of the MC, Pereira et al. (2024) investigated variations in muscle strength throughout the MC. They identified that although literature indicates hormonal fluctuations, mainly during the late follicular and luteal phases, which can affect muscle strength, these fluctuations were not observed in women practicing resistance training, who maintained consistent strength throughout the MC. The same was observed in structural conditions, where Taş and Aktaş (2020) did not identify significant differences in stiffness, elasticity, and muscle tone in 30 physically active women.

Furthermore, the findings of this study suggest a profile of athletes who are more vulnerable to injuries and consequently more affected by hormonal fluctuations of the MC. This profile includes characteristics such as older age ($p < 0.001$), shorter time as an athlete ($p < 0.001$), higher weekly training frequency ($p < 0.001$), and greater exposure due to participation in a higher number of annual competitions ($p < 0.001$).

A relevant factor that can alter hormonal conditions in different phases of the MC is the use of contraceptives. These medications can modify hormonal levels, such as estrogen and progesterone, leading to changes in muscle strength and connective tissue responses, potentially influencing joint instability and injury incidence (Nédélec et al., 2021).

However, this study did not observe significant differences in injury rates between athletes using and not using contraceptives in any phase of the MC. Similar results were found by Herzog et al. (2020), who, in a 5-year study, did not observe differences in knee injury incidence between women using and not using contraceptives. Such results may be justified by physical performance, as demonstrated by Pereira et al. (2024), who did not find strength variations between women using and not using contraceptives, and by Ekenros et al. (2022), who assessed 1,086 athletes from 57 different sports and found no significant differences in athletes' physical conditions.

Conclusion

We conclude that the luteal and late follicular phases of the MC are significantly associated with an increased risk of injuries among athletes, while the early follicular and ovulatory phases did not show statistically significant associations. Athletes using contraceptives exhibited a higher incidence of injuries during the luteal phase, while those not using contraceptives had a higher incidence during the late follicular phase. The ovulatory and early follicular phases recorded lower injury incidences in both groups, suggesting that contraceptive use may alter the injury pattern throughout the MC.

These findings have significant practical implications for injury management in female athletes. MC can be a determining factor in injury vulnerability, and adapting training and recovery programs based on the phases of the cycle may help prevent injuries. Additionally, the difference observed between athletes who use contraceptives and those who do not offers new perspectives for personalizing training strategies.

However, this study, conducted retrospectively, may limit a comprehensive understanding of the relationships between MC and injury vulnerability, and does not fully address the biological and training characteristics of more susceptible athletes. Therefore, we recommend conducting prospective studies that monitor injuries in real-time and investigate more thoroughly the correlations between MC and injuries. This will provide more robust data for the development of more effective training programs aimed at reducing injury vulnerability among athletes and improving athletic performance. This analysis may also contribute to future research, guiding new approaches to athlete health and performance improvement.

Disclosure statement

No potential conflict of interest was reported by the author(s)

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