

ORIGINAL RESEARCH

The effects of menstrual cycle phases on anaerobic and short-term maximal performances and mood states in female athletes

Wafa Jribi¹, Amine Souissi^{2✉}, Helmi Ben Saad², Nafaa Souissi¹, Kais El Abed¹, and Abderraouf Ben Abderrahman³

¹High Institute of Sport and Physical Education of Sfax, University of Sfax, Sfax, Tunisia; ²University of Sousse, Faculty of Medicine of Sousse, Farhat HACHED Hospital, Research Laboratory (Heart failure, LR12SP09), Sousse, Tunisia; and ³High Institute of Sport and Physical Education, Manouba University, Ksar-Saïd, Tunisia

Abstract

Background: The effect of menstrual cycle phases (MCPs) on athletic performance remains inconclusive. While hormonal fluctuations throughout the cycle may influence performance, the impact on anaerobic and short-term maximal performance, as well as mood states, has yet to be fully understood. **Objective:** To investigate the effect of MCPs on anaerobic and short-term maximal performances, as well as mood states among physically active young females. **Methods:** Fourteen moderately active female athletes (age 21 ± 2 years, height 162 ± 5 cm, body mass 56.0 ± 4.0 kg) undertook squat jump, countermovement jump, and Wingate tests in randomized three MCPs (menstrual, MP; luteal, LP; and follicular, FP). Females were asked to respond to self-administered questionnaires (Profile of Mood States and Hooper) at the beginning of each session. **Results:** The results of the present study indicated that the peak power and mean power assessed by the Wingate test were significantly higher in the LP compared to the MP and FP ($p < .001$ and $p < .01$, respectively). Similarly, the score vigor was higher in LP compared to the MP and FP. Moreover, stress, sleep, and fatigue were significantly higher ($p < .001$) in the MP compared to the FP and LP. On the other hand, the performance of squat and countermovement jumps, as well as the fatigue index assessed through the Wingate test, were unaffected by MCP ($p > .05$). No significant differences were observed for anxiety, anger, confusion, depression, interpersonal relationships, and delayed onset muscle soreness ($p > .05$) in the different MCP. **Conclusions:** MCP did not influence short-term maximal performance. However, it may have an impact on anaerobic performance, and this influence could be attributed to physiological and/or psychological factors.

Keywords: blood loss, exercise, hormonal fluctuations, fatigue, physical performance

Introduction

The menstrual cycle (MC) is known to influence physical performance and mood in female athletes due to hormonal fluctuations that occur across its phases (Greenhall et al., 2021; Tounsi et al., 2018). These changes can affect various factors, including energy levels, thermoregulation, perception of pain, and psychological states (Greenhall et al., 2021; Tounsi et al., 2018). Findings by Paludo et al. (2020) suggest that while a rise in estradiol concentration during the mid-luteal phase may lead to a slight reduction in physical performance, most exercise outcomes and emotional states remain unaffected across different menstrual phases, indicating that the physiological impact of the MC on female athletes is still unclear.

In the last four decades, there has been an increase in the number of females participating in physical exercise (Fink et al., 2015). For instance, the percentage of female athletes increased from 24% in the Olympic Games in Los Angeles in 1984 to 44% in London in 2012, and 45% in Rio in 2016 (with 4,700 females among the 10,500). Moreover, the female athletes at the 2018 Youth Olympic

Games in Buenos Aires, Argentina, achieved a significant milestone by representing the first fully sex-balanced Olympic event (Toscano & Molgaray 2021). Despite the progressive increase in the participation of females in sports over the years, research on the physiological and biological responses to exercise in female athletes is still lacking (Jribi et al., 2024).

The effects of MC phase (MCP) on cardiovascular and ventilatory responses to aerobic exercise, in addition to thermoregulatory control, have been extensively studied in females (Greenhall et al., 2021; Julian et al., 2017; Tounsi et al., 2018). However, a few studies have assessed the effect of MCP on the performance of short-term and anaerobic exercises, and the results have been equivocal (Dokumacı & Hazır et al., 2019). Several studies have shown that MCP did not affect short-term performances (Ghazel et al., 2022; Romero-Moraleda et al., 2019). Furthermore, it has been reported that MCP neither affects Wingate test performances (15 s; Lara et al., 2020) nor explosive half-squat test performances (Romero-Moraleda et al., 2019) in athletic females. On the other hand, Percivalle et al. (2007) identified that anaerobic performance (assessed

✉ Corresponding author: Amine Souissi, e-mail amine.swissi@gmail.com, ORCID® record <https://orcid.org/0000-0003-2072-2425>

Article history: Received March 14 2024, Accepted August 21 2025, Published September 5 2025

Copyright: © 2025 The Author(s). Published by Palacký University Olomouc. This is an open access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. This license does not cover any third-party material that may appear with permission in the article.

by an Ergocycle: 10 repeated-cycling 6-s maximal sprints) was better in the luteal phase (LP) compared to the other phases. These results were supported by Guo et al. (2005), who highlighted that the sprint performances of 100 and 200 meters were better in the LP compared to other phases. Otherwise, Parish et al. (1987) reported that the average power output during the Wingate anaerobic test was lower in the menstrual phase (MP) and LP compared to the follicular phase (FP). While the previously mentioned findings suggested an impact of MCP on anaerobic performance, it is still difficult to determine a clearly defined effect of MCP on anaerobic performance, possibly due to the wide range of factors that may be influenced by MCP. The majority of research investigating the effect of MCP on mood states focused on a fairly small range of psychological variables (*i.e.*, negative mood states), and most of these studies focused only on MP (Endicott et al., 1993). The literature still lacks comprehensive psychological studies covering the entire cycle (Ghazel et al., 2022).

Considering the aforementioned points, the present study aimed to examine the effect of MCP on short-term and anaerobic performances as well as mood, fatigue, stress, sleep, and muscle soreness in a sample of female athletes. We hypothesized that psychological and physical variables could be influenced by MCP.

Methods

Participants

Fourteen physically active females in various sports disciplines (gymnastics: $n = 4$, judo: $n = 4$, handball: $n = 1$, karate: $n = 5$) volunteered to participate in the study, which took place between the end of June and the beginning of September 2023. Participants were required to meet several inclusion criteria: they had to be nonsmokers, not using hormonal contraception, and free from any musculoskeletal injuries of the lower limbs for at least one year prior to recruitment, with no history of orthopedic surgery. Additionally, participants needed to have regular MCs (21–35 days) and could not be pregnant or lactating. Participants also had to maintain a stable training regimen without significant variations in intensity or volume during the four weeks preceding data collection.

Exclusion criteria included participants with a history of neurological, cardiovascular, metabolic, endocrine, or psychiatric disorders, those with excessive alcohol or caffeine consumption, and those taking medications or supplements that could affect physical, cognitive, or psychological performance. After receiving a verbal description of the research protocol, the purpose of the study, and potential risks, as well as the experimental protocol, the participants provided written informed consent. The study was conducted in accordance with the Declaration of Helsinki guidelines and was approved by the Ethics Committee of the medical unit of the Institute of Physical and Sports Education of Sfax (Tunisia).

Sample size

The sample size was calculated using the following formula (Faul et al., 2007):

$$N = ((Z_{\alpha/2} + Z_{\beta})/d)^2$$

where $Z_{\alpha/2}$ = Z -score for the two-sided significance level (for 90% confidence, $Z_{\alpha/2} = 1.645$), Z_{β} = Z -score for the desired power (for 80% power, $Z_{\beta} = 0.84$), d = expected effect size (Cohen's d , $d = 0.66$).

The injection of the aforementioned data in the predictive equation gave a sample size of 14 participants.

Experimental design

Participants attended two familiarization visits two weeks prior to the start of the experiment, during which they were acquainted with the experimental protocol. The participants engaged in three experimental sessions (MP, FP, and LP), and were asked to respond to a general questionnaire related to menstrual characteristics during the three phases. Menstrual characteristics were: menarche age (10–12, 13–14, 15–17 years), cycle length (21, 22–27, 28–35 days), menstrual symptoms (yes/no), menstrual flow (≤ 4 , 5–6, ≥ 7 days), menstrual blood loss (scarce, average, abundant), menstrual pain (yes/no), and pain intensity (mild, moderate, severe). Then, the participants filled out the French version of the Profile of Mood States questionnaire (POMS-f; Cayrou et al., 2000) and the Hooper questionnaire (Hooper et al., 1995) followed by a sequence of tests, including an squat jump (SJ) test, countermovement (CMJ) test, and Wingate test (Figure 1).

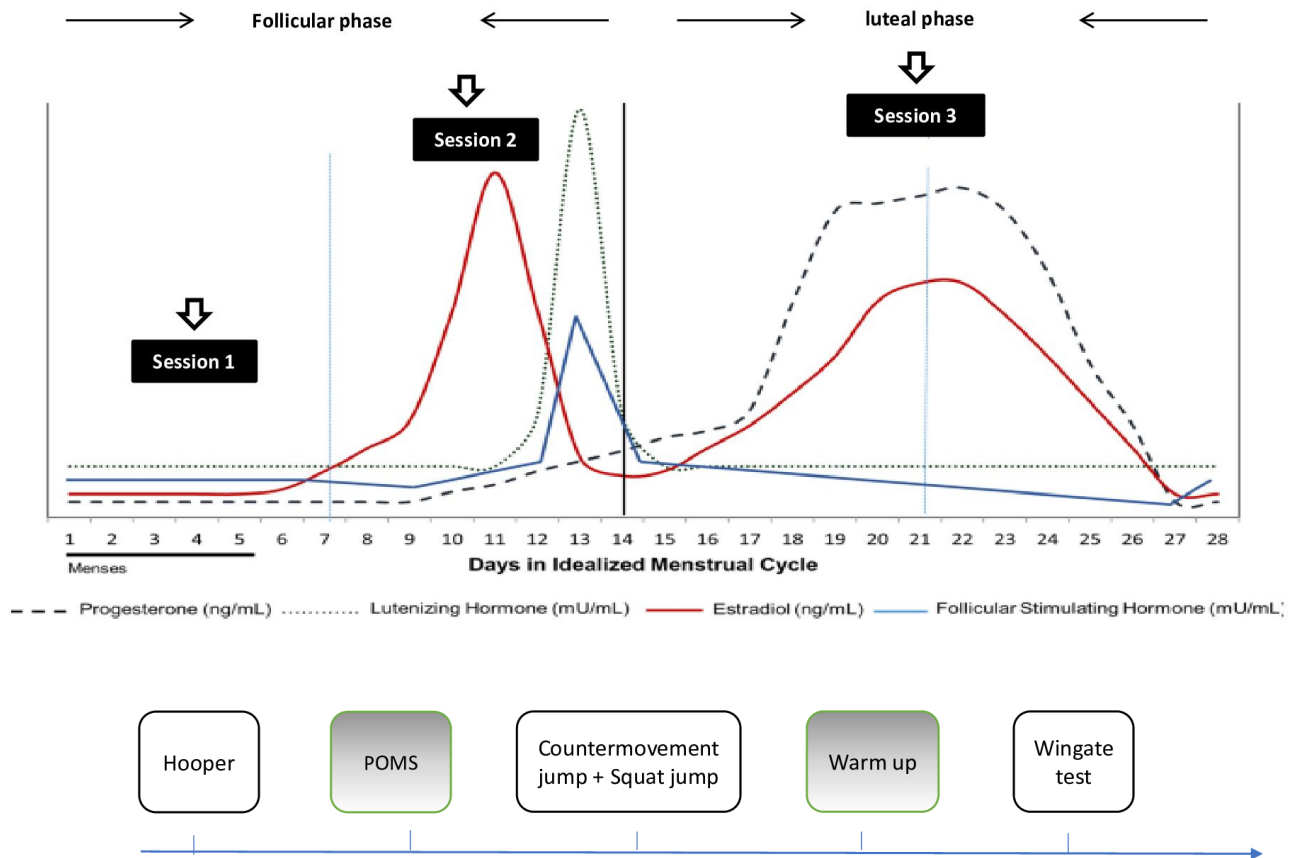
In both the SJ and CMJ tests, three trials were executed with a 2-min recovery period between each trial. The best attempt was subsequently selected for analysis. All tests were carried out over a span of two months under thermoneutral conditions (Souissi et al., 2020). All sessions were performed at the same time of the day (16:00 h) to minimize the effects of diurnal variation in the measured parameters (Souissi et al., 2020).

Determination of menstrual cycle phases

Participants completed a menstrual diary twice a month, recording details such as the date of menses, duration of menses, and the intensity of blood flow and discomfort (Table 1). Participants were requested to document this information for six months to assess their MC profile (Janse De Jonge, 2003). In addition to period (Romero-Moraleda et al., 2019), the study utilized body temperature measurements (Tenan et al., 2013, 2016) and assessment of luteinizing hormone urinary peak (Bambaeichi et al., 2004) to determine the duration and onset of each MCP.

Mobile app My Calendar (<https://play.google.com/store/apps/details?id=com.veevapps.periodcalendar>) was used to record the daily menstrual diary, including the length and the date of menses. Since the ovulation occurrence is accompanied by an increase in central temperature by 0.5 °C (Auclair-Ronzaud et al., 2023), rectal temperature was recorded every day at 16:00 (Reilly, 2000). Moreover, starting from the eighth day of each MC, participants commenced the use of home ovulation testing kits to

Figure 1 Schematic illustration of the experimental protocol



16:00 h

Table 1 Menstrual characteristics of the 14 female athletes

Menstrual variable / Category	n
Menarche age (years)	
10–12	5
13–14	7
15–17	2
Presence of menstrual symptoms	
Yes	13
No	1
Cycle length (days)	
21	2
22–27	3
28–34	8
35	1
Menstrual flow (days)	
≤ 4	3
5–6	6
≥ 7	5
Menstrual blood loss	
Scarce	1
Average	2
Abundant	11
Menstrual pain	
Yes	12
No	2
Pain intensity	
Mild	2
Moderate	5
Severe	7

confirm the day of ovulation. Testing was maintained until positive results were obtained.

Wingate test

The Wingate test was performed using a Monark Model 894E (Monark Exercise, Vansbro, Sweden). The test involves a 30-s pedaling exercise at maximum speed against a constant braking force (0.087 kg per kg of body mass; Bar-Or, 1987). In each session, the braking load for each participant is determined based on his/her body mass measurement. To avoid the intra-individual effects of posture changes, the position of the feet on the pedals, seat height, and upper body position was adjusted based on the participant’s preference (Rohsler et al., 2020). The Wingate test included peak power (highest mechanical power), mean power (average power) for 30 s, and fatigue index (Castañeda-Babarro, 2021).

The power is calculated as:

$$P = F * v,$$

where P is the power, either peak or average in Watts; F is the braking force in kilograms; and v is the pedaling speed in revolutions per minute (Souissi et al., 2010).

CMJ test

The CMJ test starts in a standing position (Donahue et al., 2021). The participant performs a downward counter movement (lower limb flexion) immediately followed by

full extension of the lower limbs (Driggers & Sato, 2018). This participant jumps as high as possible (Chtourou et al., 2013). The participant performed three trials in each test with a 2-min recovery between trials, and the best attempt was recorded.

SJ test

The SJ test starts in a “squat” position (Donahue et al., 2021). The knees are bent, and the angle formed by the thighs and legs is approximately equal to 90° (Driggers & Sato et al., 2018). During this jump, the participant is instructed not to perform a downward countermovement and to jump as high as possible (Driggers & Sato et al., 2018).

The participants performed three trials in every test with a 2-min recovery time between trials, and the best one was recorded. A 3-min rest period was provided between SJ and CMJ to prevent any potential fatigue effect. During all vertical jumps, hands were placed on the hips to avoid any swinging motion with the arms that would allow jumping higher. Jumping performances were monitored with an optical jump system (Optojump Next; Microgate, Bolsano, Italy), see Glatthorn et al. (2011).

Hooper questionnaire

Participants were asked to respond subjectively about:

1. Quality of sleep (concerning the night preceding the evaluation),
2. Quantity of perceived stress,
3. Fatigue,
4. Muscle soreness according to a Hooper et al. (1995) questionnaire.

Each of the four items was scored on a 7-point scale on which 1 and 7 represented *very, very good* and *very, very poor* wellness ratings, respectively.

POMS

The French adapted version (Cayrou et al., 2000, 2003) of the POMS (McNair et al., 1971) was used. POMS, which is a self-report questionnaire used to assess subjective mood states, assesses seven mood states (tension, depression, anger, endurance, fatigue, confusion, and relationships) from 65 adjectives. Each adjective was rated from 0 (*not at all*) to 4 (*very strong*), with higher scores indicating a more negative mood state.

Statistical analyses

All the statistics were analyzed using Statistica for Windows (Version 10; Tulsa, OK, USA). The measured parameters were presented as mean, standard deviation and 95% confidence interval. Before conducting such analyses, the normality of distributions was tested with Shapiro-Wilk's test, the test results were not statistically significant. Data were analyzed using a one-way analysis of variance. A post hoc Tukey's HSD analysis was conducted to evaluate pairwise differences. Effect sizes were calculated as partial eta-squared to assess the potential practical significance of the findings.

The following three mean changes were calculated:

1. MP vs. FP = $100 * (MP - FP)/MP$,
2. MP vs. LP = $100 * (MP - LP)/MP$,
3. FP vs. LP = $100 * (FP - LP)/FP$.

The level of significance was set at $p < .05$ for all statistical analyses.

Results

Fourteen female athletes were included (age 21 ± 2 years, body height 162 ± 5 cm, body mass 56 ± 4 kg, and training volume per week 6 ± 2 hours). Table 1 outlines the menstrual characteristics of the 14 participants.

Wingate test

Table 2 shows the effects of MCP on peak power, mean power, and fatigue index during the Wingate test. Only peak and mean powers were influenced by MCP with medium effect size. Post-hoc analysis revealed that they were significantly higher during the LP compared to the MP (mean changes were -13% for peak power and -12% for mean power).

CMJ and SJ tests

Table 3 shows the effects of MCP on CMJ and SJ heights. MCP has no effect on CMJ, flight time of CMJ, SJ, and flight time of SJ.

Hooper

Table 4 shows the effects of MCP on fatigue, stress, sleep, and muscle soreness registered by the Hooper questionnaire. Only fatigue, sleep quality, stress, and Hooper total score were influenced by MCP, with a medium effect size for sleep and large effect sizes for the remaining data. Post-hoc analysis revealed that their scores were significantly higher during the MP compared to FP (mean changes were

Table 2 Menstrual cycle phase effects on peak power, mean power, and fatigue index during the Wingate test ($N = 14$)

Variable	Menstrual cycle phase			Mean change (%)			ANOVA p	η_p^2	Post-hoc p
	MP	FP	LP	MP vs. FP	MP vs. LP	FP vs. LP			
Peak power ($W \cdot kg^{-1}$)	105 ± 6 [101, 108]	110 ± 9 [105, 115]	118 ± 14 [110, 126]	-5 ± 4 [-9, -1]	-13 ± 11 [-19, -6]	-7 ± 8 [-12, -2]	.0069	.2253	MP vs. LP: .0051
Mean power ($W \cdot kg^{-1}$)	76 ± 6 [73, 80]	79 ± 8 [75, 84]	85 ± 6 [81, 88]	-4 ± 13 [-12, 3]	-12 ± 11 [-18, -5]	-7 ± 7 [-11, -3]	.0061	.2302	MP vs. LP: .0046
Fatigue index (%)	60 ± 8 [56, 65]	59 ± 12 [53, 66]	59 ± 7 [55, 62]	-1 ± 25 [-15, 14]	0 ± 26 [-15, 15]	-1 ± 20 [-12, 10]	.8626	.0076	–

Note. MP = menstrual phase; FP = follicular phase; LP = luteal phase; ANOVA = analysis of variance. Variable and change values are presented as mean \pm standard deviation [95% confidence interval].

24% for fatigue, 22% for sleep, 22% for stress, and 18% for total score) and to LP (mean changes were 26% for fatigue, 25% for sleep, 34% for stress, and 24% for total score).

POMS

Table 5 shows the effects of MCP on the items of the Profile of Mood States questionnaire. Only fatigue and vigor were influenced by MCP, with a medium effect size. Post-hoc analysis revealed that Fatigue score was significantly higher

during the MP compared to FP (mean change = 39%) and LP (mean change = 40%), and Vigor score was significantly lower by 46% during the FP compared to the LP.

Discussion

The main findings of the present study revealed that MCP can impact certain athletic performances, including anaerobic performance. In particular, the LP exhibited higher

Table 3 Menstrual cycle phase effects on countermovement jump (CMJ) and squat jump (SJ) heights (N = 14)

Variable	Menstrual cycle phase			Mean change (%)			ANOVA <i>p</i>	η_p^2
	MP	FP	LP	MP vs. FP	MP vs. LP	FP vs. LP		
CMJ (cm)	26.25 ± 2.60 [24.75, 27.75]	26.54 ± 3.41 [24.57, 28.51]	27.01 ± 3.47 [25.01, 29.01]	-1 ± 7 [-5, 3]	-3 ± 12 [-10, 4]	-2 ± 10 [-8, 4]	.8169	.0103
Flight time of CMJ (s)	0.45 ± 0.03 [0.43, 0.47]	0.46 ± 0.02 [0.45, 0.47]	0.47 ± 0.03 [0.45, 0.4]	-2 ± 6 [-5, 2]	-5 ± 9 [-10, 0]	-3 ± 6 [-6, 1]	.2231	.0740
SJ (cm)	25.08 ± 2.49 [23.64, 26.51]	25.52 ± 2.91 [23.84, 27.20]	25.85 ± 3.40 [23.88, 27.82]	-2 ± 8 [-6, 3]	-3 ± 10 [-9, 2]	-1 ± 6 [-5, 2]	.7861	.0123
Flight time of SJ (s)	0.44 ± 0.03 [0.42, 0.45]	0.45 ± 0.02 [0.44, 0.47]	0.46 ± 0.03 [0.44, 0.48]	-4 ± 7 [-8, 0]	-5 ± 7 [-9, -1]	-1 ± 4 [-3, 1]	.1215	.1024

Note. MP = menstrual phase; FP = follicular phase; LP = luteal phase; ANOVA = analysis of variance. Variable and change values are presented as mean ± standard deviation [95% confidence interval].

Table 4 Menstrual cycle phase effects on fatigue, stress, sleep, and, muscle soreness registered by the Hooper questionnaire (N = 14)

Variable	Menstrual cycle phase			Mean change (%)			ANOVA <i>p</i>	η_p^2	Post-hoc <i>p</i>
	MP	FP	LP	MP vs. FP	MP vs. LP	FP vs. LP			
Fatigue	5.79 ± 1.05 [5.18, 6.39]	4.29 ± 0.99 [3.71, 4.86]	4.21 ± 1.25 [3.49, 4.94]	24 ± 21 [12, 36]	26 ± 22 [14, 39]	-3 ± 36 [-24, 18]	0.0006	.3117	MP vs. FP: .0026 MP vs. LP: .0017
Sleep	6.07 ± 0.83 [5.59, 6.55]	4.64 ± 1.55 [3.75, 5.54]	4.50 ± 1.61 [3.57, 5.43]	22 ± 30 [4, 39]	25 ± 26 [10, 40]	-17 ± 89 [-69, 34]	0.0073	.2231	MP vs. FP: .0240 MP vs. LP: .0120
Stress	5.50 ± 1.29 [4.76, 6.24]	4.14 ± 1.03 [3.55, 4.74]	3.43 ± 1.16 [2.76, 4.10]	22 ± 21 [10, 34]	34 ± 30 [16, 51]	7 ± 35 [-14, 27]	0.0001	.3706	MP vs. FP: .0102 MP vs. LP: .0002
Muscle soreness	4.64 ± 1.78 [3.61, 5.67]	4.64 ± 1.15 [3.98, 5.31]	4.36 ± 1.69 [3.38, 5.33]	-18 ± 60 [-53, 17]	3 ± 28 [-13, 19]	-7 ± 8 [-12, -2]	0.8566	.0079	-
Total score	22.00 ± 2.99 [20.28, 23.72]	17.71 ± 2.81 [16.09, 19.34]	16.50 ± 3.48 [14.49, 18.51]	18 ± 16 [9, 27]	24 ± 17 [14, 34]	4 ± 28 [-12, 20]	0.0001	.3831	MP vs. FP: .0022 MP vs. LP: .0002

Note. MP = menstrual phase; FP = follicular phase; LP = luteal phase; ANOVA = analysis of variance. Variable and change values are presented as mean ± standard deviation [95% confidence interval].

Table 5 Menstrual cycle phase effects on the items of the Profile of Mood States questionnaire (N = 14)

Variable	Menstrual cycle phases			Mean change (%)			ANOVA <i>p</i>	η_p^2	Post-hoc <i>p</i>
	MP	FP	LP	MP vs. FP	MP vs. LP	FP vs. LP			
Anxiety (au)	11.64 ± 8.07 [6.98, 16.30]	11.93 ± 7.61 [7.53, 16.32]	11.14 ± 7.38 [6.88, 15.40]	-19 ± 55 [-50, 13]	-10 ± 48 [-38, 18]	-16 ± 91 [-69, 36]	.9633	.0019	-
Anger (au)	14.00 ± 10.36 [8.02, 19.98]	14.21 ± 12.22 [7.16, 21.27]	13.57 ± 13.10 [6.01, 21.13]	-5 ± 82 [-60, 50]	5 ± 61 [-36, 46]	-27 ± 147 [-112, 58]	.9895	.0005	-
Confusion (au)	12.29 ± 6.99 [8.25, 16.32]	12.21 ± 5.92 [8.79, 15.64]	12.14 ± 6.77 [8.23, 16.05]	-11 ± 59 [-45, 23]	-6 ± 43 [-30, 19]	-9 ± 46 [-36, 8]	.9983	.0001	-
Depression (au)	13.50 ± 15.73 [4.42, 22.58]	15.93 ± 12.58 [8.67, 23.19]	10.36 ± 10.66 [4.20, 16.51]	-178 ± 422 [-446, 90]	-9 ± 81 [-60, 42]	28 ± 65 [-11, 67]	.5374	.0313	-
Fatigue (au)	18.07 ± 4.48 [15.48, 20.66]	11.43 ± 5.43 [8.29, 14.56]	10.93 ± 7.69 [6.49, 15.37]	39 ± 24 [25, 53]	40 ± 35 [20, 60]	-20 ± 104 [-80, 40]	.0048	.2395	MP vs. FP: .0157 MP vs. LP: .0089
Vigor (au)	16.64 ± 6.83 [12.70, 20.59]	16.21 ± 6.00 [12.75, 19.68]	21.79 ± 5.41 [18.66, 24.91]	-12 ± 69 [-52, 28]	-52 ± 85 [-101, -3]	-46 ± 49 [-74, -18]	.0366	.1560	FP vs. LP: .0499
Interpersonal relationship (au)	15.07 ± 6.16 [11.52, 18.63]	14.29 ± 6.38 [10.60, 17.97]	14.57 ± 5.49 [11.40, 17.74]	-3 ± 54 [-34, 28]	-1 ± 35 [-21, 19]	-15 ± 53 [-45, 6]	.9408	.0031	-
Emotional distress scores (au)	40.00 ± 41.30 [16.16, 63.84]	41.79 ± 39.88 [18.76, 64.81]	41.93 ± 41.12 [18.19, 65.67]	-67 ± 261 [-217, 84]	-52 ± 187 [-160, 57]	-331 ± 780 [-781, 120]	.9903	.0004	-

Note. MP = menstrual phase; FP = follicular phase; LP = luteal phase; ANOVA = analysis of variance, au = arbitrary units. Variable and change values are presented as mean ± standard deviation [95% confidence interval].

peak and mean powers compared to the MP and FP, along with an increase in vigor. On the other hand, the MP demonstrated the lowest anaerobic performance compared to the FP and LP, with the lowest performance during the Wingate test, accompanied by a significant rise in stress and fatigue.

Our results are consistent with previous research, indicating that MCP had no significant effect on the performance of CMJ and SJ tests (Ghazel et al. 2022). This also aligns with previous studies suggesting that performance requiring rapid force production is not influenced by MCP (Ghazel et al., 2022; Romero-Moraleda et al., 2019). Indeed, the study of Romero-Moraleda et al. (2019) reported no difference in strength, speed, and power output during half squats performed at 20%, 40%, 60%, and 80% of one-repetition maximum among 13 athletic females. Moreover, Tounsi et al. (2018) confirmed this outcome by investigating the performance of the five-jump test among eumenorrheic footballers across various MCP. Furthermore, García-Pinillos et al. (2021) examined the effects of MCP on resistance-trained females. Their results showed that the performance of SJ, CMJ, and drop jump from a 30 cm box did not differ according to MCP.

Furthermore, our results are in agreement with previous research, indicating that MCP can have an impact on anaerobic performance (Guo et al., 2005; Parish & Jake-man, 1987; Percivalle et al., 2007). On the contrary, in a study conducted by Tsampoukos et al. (2011), 11 female athletes with regular menstruation underwent a repetitive sprint test. The results indicated that menstruation had no significant impact on their performance or recovery rate. Similarly, Çakmakçı et al. (2005) identified no significant differences in anaerobic performance (assessed through the Wingate test) between the MP and FP. Indeed, the contrast between our findings and those studies that did not observe an effect of MCP on anaerobic performance might be attributed to the heavy menstrual flow identified in our study during the MP. Previous studies, such as Hasson (2012), have proposed a potential association between fatigue or anemia and significant menstrual blood loss in female athletes, which is supported by our findings. Indeed, it has been demonstrated that abundant menstrual blood loss can result in iron depletion and anemia, potentially exacerbating pre-existing anemia in female athletes. We highlight that our results reveal that 78% of our participants experience abundant menstrual blood loss. Consequently, this significant blood loss, which is often accompanied by pain in some females, could serve as a plausible explanation for the observed decline in anaerobic performance during the MP. Moreover, Karacan and Günay (2003) have suggested on the other hand that both physiological and psychological negative effects during the MP can be detrimental to performance. In this context, it is believed that declines in performance could be attributed to behavioral changes, manifesting as fatigue, stress, and a reduction of sleep quality during the MP. In agreement with several studies reporting that MP may affect not only the physical performance of athletes (Knowles et al., 2019), but also influence their daily life (Karlsson et al., 2014).

Moreover, Tasmektepligil et al. (2010) investigated the effect of MCs on vertical jump height and anaerobic performance in 30 sportswomen. Participants underwent testing on three different days during their monthly cycles: 26th–28th (before menstruation), 1st–6th (during menstruation), and 7th–12th (after menstruation). The authors reported higher performance values in the early FP compared to other MCPs. The divergence between our data and that of Tasmektepligil et al. (2010) could be explained by the specific period during which the physical tests were conducted. In the present study, the measurements were conducted during the early LP when estrogen levels were higher compared to the early FP. Since research has demonstrated that the elevated level of estrogen during the early LP is linked to an increase in force production (Štefanovský et al., 2016; due to the substantial storage and utilization of adenosine triphosphate and phosphocreatine), we propose that the heightened estrogen levels during the early LP may have played a role in enhancing performance on the Wingate test. Furthermore, the present study revealed that the POMS-vigor scores were higher during the LP. This result indeed supports the earlier hypothesis. Interestingly, future research should focus on discovering the mechanisms explaining the impact of MCP on anaerobic performance, which may be related to physiological and/or psychological factors.

Like all studies, the present research has some limitations. The primary one was the absence of measurements of estrogen and progesterone concentrations across different MCPs, which would have provided valuable insights into the hormonal fluctuations and their potential effects on performance. Furthermore, the study did not account for other external factors such as sleep quality, nutrition, or stress levels, all of which could influence performance outcomes. Additionally, the athletes' training season was not controlled, which may have introduced variability due to fluctuations in training load or competition schedules. Moreover, this study focused on short-duration performance, which limits the applicability of the findings to exercises involving longer durations or a broader range of physical activities. The influence of MCPs may vary depending on the sport discipline. Endurance sports, strength-based events, and skill-focused activities may each respond differently to hormonal and mood changes. This highlights the need for sport-specific research when assessing the impact of MCPs on female athletic performance.

Conclusions

Our findings indicated variations in specific athletic parameters across different MCPs. The results suggest an enhancement in anaerobic performance during the LP compared to both the FP and MP, along with an increase in vigor. In contrast, the MP exhibits the lowest anaerobic performance relative to the FP and LP, accompanied by a significant rise in stress and fatigue. These findings have important practical implications, emphasizing the potential benefits of tailoring training programs based on MCP to optimize performance. Additionally, our results suggested

that considering hormonal factors in training planning might improve the effectiveness of athletic interventions. This study contributes to the existing literature by providing a deeper understanding of the effects of the MCP on anaerobic performance.

Acknowledgments

The authors would like to thank the students who assisted in the project, as well as each of the participants for their selfless participation.

Conflict of interest

The authors report no conflict of interest.

References

- Auclair-Ronzaud, J., Barrier-Battut, I., Bozec, J., Potier, P. H., Dubois, C., & Wimel, L. (2023). Relationship between ovulation and body temperature in the mare: A preliminary study. *Journal of Equine Veterinary Science*, 130, Article 104927. <https://doi.org/10.1016/j.jevs.2023.104927>
- Bambaeichi, E., Reilly, T., Cable, N. T., & Giacomoni, M. (2004). The isolated and combined effects of menstrual cycle phase and time-of-day on muscle strength of eumenorrhic females. *Chronobiology International*, 21(4–5), 645–660. <https://doi.org/10.1081/CBI-120039206>
- Bar-Or, O. (1987). The Wingate anaerobic test. An update on methodology, reliability and validity. *Sports Medicine*, 4(6), 381–394. <https://doi.org/10.2165/00007256-198704060-0000>
- Çakmakçı, E., Sanioğlu, A., Patlar, S., Çakmakçı, O., & Çinar, V. (2005). Menstruasyonun anaerobik güce etkisi [Effect of menstruation on anaerobic strength]. *SPORMETRE Beden Eğitimi ve Spor Bilimleri Dergisi*, 3(4), 145–149. https://doi.org/10.1501/Sporm_0000000054
- Castañeda-Babarro, A. (2021). The Wingate Anaerobic Test, a narrative review of the protocol variables that affect the results obtained. *Applied Sciences*, 11(16), Article 7417. <https://doi.org/10.3390/app11167417>
- Cayrou, S., Dickès, P., & Dolbeault, S. (2003). Version française du Profile of Mood States (POMS-f) [French version of the Profile of Mood States (POMS-f)]. *Journal de Thérapie Comportementale et Cognitive*, 13(2), 83–88.
- Cayrou, S., Dickès, P., Gauvin-Piquard, A., Dolbeault, S., Callahan, S., & Rogé, B. (2000). Validation de la traduction française du POMS (Profile of Mood States) [Validation of the French translation of the POMS (Profile of Mood States)]. *Psychologie et Psychométrie*, 21(4), 5–22.
- Chtourou, H., Aloui, A., Hammouda, O., Chaouachi, A., Chamari, K., & Souissi, N. (2013). Effect of static and dynamic stretching on the diurnal variations of jump performance in soccer players. *PLOS ONE*, 8(8), Article e70534. <https://doi.org/10.1371/journal.pone.0070534>
- Dokumaci, B., & Hazir, T. (2019). Effects of the menstrual cycle on running economy: Oxygen cost versus caloric cost. *Research Quarterly for Exercise and Sport*, 90(3), 318–326. <https://doi.org/10.1080/02701367.2019.1599800>
- Donahue, P. T., Wilson, S. J., Williams, C. C., Hill, C. M., & Garner, J. C. (2021). Comparison of counter movement and squat jumps performance in recreationally trained males. *International Journal of Exercise Science*, 14(1), 462–472. <https://doi.org/10.70252/ixqb8485>
- Driggers, A. R., & Sato, K. (2018). The effects of vertically oriented resistance training on golf drive performance in collegiate golfers. *International Journal of Sports Science & Coaching*, 13(4), 598–606. <https://doi.org/10.1177/174795411774337>
- Endicott, J. (1993). The menstrual cycle and mood disorders. *Journal of Affective Disorders*, 29(2–3), 193–200. [https://doi.org/10.1016/0165-0327\(93\)90033-g](https://doi.org/10.1016/0165-0327(93)90033-g)
- Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39(2), 175–191. <https://doi.org/10.3758/BF03193146>
- Fink, E., Begeer, S., Peterson, C. C., Slaughter, V., & de Rosnay, M. (2015). Friendlessness and theory of mind: A prospective longitudinal study. *British Journal of Developmental Psychology*, 33(1), 1–17. <https://doi.org/10.1111/bjdp.12060>
- García-Pinillos, F., Bujalance-Moreno, P., Lago-Fuentes, C., Ruiz-Álias, S. A., Domínguez-Azpiroz, I., Mecías-Calvo, M., & Ramírez-Campillo, R. (2021). Effects of the menstrual cycle on jumping, sprinting and force-velocity profiling in resistance-trained women: A preliminary study. *International Journal of Environmental Research and Public Health*, 18(9), Article 4830. <https://doi.org/10.3390/ijerph18094830>
- Ghazel, N., Souissi, A., Chtourou, H., Aloui, G., & Souissi, N. (2022). The effect of music on short-term exercise performance during the different menstrual cycle phases in female handball players. *Research in Sports Medicine*, 30(1), 50–60. <https://doi.org/10.1080/15438627.2020.1860045>
- Glaththorn, J. F., Gouge, S., Nussbaumer, S., Stauffacher, S., Impellizzeri, F. M., & Maffiuletti, N. A. (2011). Validity and reliability of Optojump photoelectric cells for estimating vertical jump height. *Journal of Strength and Conditioning Research*, 25(2), 556–560. <https://doi.org/10.1519/JSC.0b013e3181ccb18d>
- Greenhall, M., Taipale, R. S., Ihalainen, J. K., & Hackney, A. C. (2021). Influence of the menstrual cycle phase on marathon performance in recreational runners. *International Journal of Sports Physiology and Performance*, 16(4), 601–604. <https://doi.org/10.1123/ijspp.2020-0238>
- Guo, H., Dong, X., & Zhang, J. (2005). Hormone levels at different menstrual cycle phases and changes of athletic performance in female athletes. *Chinese Journal of Tissue Engineering Research*, 53, 188–190.
- Hasson, K. A. (2012). From bodies to lives, complainers to consumers: Measuring menstrual excess. *Social Science & Medicine*, 75(10), 1729–1736. <https://doi.org/10.1016/j.socscimed.2012.07.005>
- Hooper, S., MacKinnon, L., & Wilson, B. (1995). Biomechanical responses of elite swimmers to staleness and recovery. *Australian Journal of Science and Medicine in Sport*, 27(1), 9–13.
- Janse de Jonge, X. A. (2003). Effects of the menstrual cycle on exercise performance. *Sports Medicine*, 33(11), 833–851. <https://doi.org/10.2165/00007256-200333110-00004>
- Jribi, W., Bougrine, H., Aloui, A., Khalfoun, J., Souissi, N., Mkacher, W., El Abed, K., & Ben Abderrahman, A. (2024). Morning-evening differences of short-term maximal performance and psychological variables in female athletes. *Frontiers in Physiology*, 15, Article 1402147. <https://doi.org/10.3389/fphys.2024.1402147>
- Julian, R., Hecksteden, A., Fullagar, H. H., & Meyer, T. (2017). The effects of menstrual cycle phase on physical performance in female soccer players. *PLOS ONE*, 12(3), Article e0173951. <https://doi.org/10.1371/journal.pone.0173951>
- Karacan, S., & Günay, M. (2003). Sporcularlarda menstruasyon e premenstrual şendromun bazı temel motorik özelliklere ve fizyolojik parametrelere etkisi [The effects of premenstrual syndrome and menstruation on some basic motoric skill and physiologic parameters in athletes]. *Gazi Beden Eğitimi ve Spor Bilimleri Dergisi*, 8(4), 49–57. <https://dergipark.org.tr/en/pub/gbesbd/issue/27978/304947>
- Karlsson, T. S., Marions, L. B., & Edlund, M. G. (2014). Heavy menstrual bleeding significantly affects quality of life. *Acta Obstetrica et Gynecologica Scandinavica*, 93(1), 52–57. <https://doi.org/10.1111/aogs.12292>
- Knowles, O. E., Aisbett, B., Main, L. C., Drinkwater, E. J., Orellana, L., & Lamon, S. (2019). Resistance training and skeletal muscle protein metabolism in eumenorrhic females: Implications for researchers and practitioners. *Sports Medicine*, 49(11), 1637–1650. <https://doi.org/10.1007/s40279-019-01132-7>
- Lara, B., Gutiérrez-Hellín, J., Ruiz-Moreno, C., Romero-Moraleda, B., & Del Coso, J. (2020). Acute caffeine intake increases performance in the 15-s Wingate test during the menstrual cycle. *British Journal of Clinical Pharmacology*, 86(4), 745–752. <https://doi.org/10.1111/bcp.14175>
- McNair, D. M., Lorr, M., & Droppleman, L. F. (1971). *Manual for the Profile of Mood States*. Educational and Industrial Testing Services.
- Paludo, A. C., Cook, C. J., Owen, J. A., Woodman, T., Irwin, J., & Crewther, B. T. (2020). The impact of menstrual-cycle phase on basal and exercise-induced hormones, mood, anxiety and exercise performance in physically active women. *Journal of Sports Medicine and Physical Fitness*, 61(3), 461–467. <https://doi.org/10.23736/s0022-4707-20-10844-2>
- Parish, H. C., & Jakeman, P. M. (1987). The effects of menstruation upon repeated maximal sprint performance. *Journal of Sports Sciences*, 5(1), 78.
- Perciavalle, V., Coco, M., Maugeri, A., & Gurrissi, L. (2007). Relations between menstrual phase and performance of an intense intermittent activity. *Acta Medica Mediterranea*, 23(15), 15–20.
- Reilly, T. (2000). The menstrual cycle and human performance: An overview. *Biological Rhythm Research*, 31(1), 29–40. [https://doi.org/10.1076/0929-1016\(200002\)31:1:1-0:FT029](https://doi.org/10.1076/0929-1016(200002)31:1:1-0:FT029)
- Rohsler, R., Campos, F. D. S., Varoni, P. R., Baumann, L., Demarchi, M., Teixeira, A. S., & Flores, L. J. F. (2020). Performance comparison in the Wingate test between standing and seated positions in competitive cyclists. *Motriz: Revista de Educação Física*, 26(2), Article e10200169. <https://doi.org/10.1590/s1980-6574202000020169>
- Romero-Moraleda, B., Coso, J. D., Gutiérrez-Hellín, J., Ruiz-Moreno, C., Grgic, J., & Lara, B. (2019). The influence of the menstrual cycle on muscle strength and power performance. *Journal of Human Kinetics*, 68, 123–133. <https://doi.org/10.2478/hukin-2019-0061>
- Serhier, Z., Bendahhou, K., Ben Abdelaziz, A., & Bennani, M. O. (2020). Fiche Méthodologique n°1: Comment calculer la taille d'un échantillon pour une étude observationnelle? [Methodological sheet n°1: How to calculate the size of a sample for an observational study?]. *La Tunisie Médicale*, 98(1), 1–7. <https://latunisiemedicale.com/index.php/tunismed/article/view/3666>
- Souissi, H., Chaouachi, A., Chamari, K., Dogui, M., Amri, M., & Souissi, N. (2010). Time-of-day effects on short-term exercise performances in 10- to 11-year-old boys. *Pediatric Exercise Science*, 22(4), 613–623. <https://doi.org/10.1123/pes.22.4.613>
- Souissi, M., Souissi, Y., Bayoudh, A., Knechtel, B., Nikolaidis, P. T., & Chtourou, H. (2020). Effects of a 30 min nap opportunity on cognitive and short-duration high-intensity performances and mood states after a partial sleep deprivation night. *Journal of Sports Sciences*, 38(22), 2553–2561. <https://doi.org/10.1080/02640414.2020.1793651>
- Štefanovský, M., Péterová, A., Vanderka, M., & Lengvarský, L. (2016). Influence of selected phases of the menstrual cycle on performance in Special judo fitness

- test and Wingate test. *Acta Gymnica*, 46(3), 136–142. <https://doi.org/10.5507/ag.2016.015>
- Tasmektepligil, M. Y., Agaoglu, S. A., Türkmen, L., & Türkmen, M. (2010). The motor performance and some physical characteristics of the sportswomen and sedentary lifestyle women during menstrual cycle. *Archives of Budo*, 6(4), 195–203. <https://archbudo.com/view/abstract/id/10626>
- Tenan, M. S., Hackney, A. C., & Griffin, L. (2016). Maximal force and tremor changes across the menstrual cycle. *European Journal of Applied Physiology*, 116(1), 153–160. <https://doi.org/10.1007/s00421-015-3258-x>
- Tenan, M. S., Peng, Y. L., Hackney, A. C., & Griffin, L. (2013). Menstrual cycle mediates vastus medialis and vastus medialis oblique muscle activity. *Medicine & Science in Sports & Exercise*, 45(11), 2151–2157. <https://doi.org/10.1249/MSS.0b013e318299a69d>
- Toscano, W., & Molgaray, D. (2021). Sport as a strategy for sustainable local development: The experience of the 2018 Youth Olympic Games in Buenos Aires, Argentina. *Local Development & Society*, 2(2), 255–270. <https://doi.org/10.1080/26883597.2021.1976054>
- Tounsi, M., Jaafar, H., Aloui, A., & Souissi, N. (2018). Soccer-related performance in eumenorrheic Tunisian high-level soccer players: Effects of menstrual cycle phase and moment of day. *Journal of Sports Medicine and Physical Fitness*, 58(4), 497–502. <https://doi.org/10.23736/S0022-4707.17.06958-4>
- Tsampoukos, A., Peckham, E. A., James, R., & Nevill, M. E. (2010). Effect of menstrual cycle phase on sprinting performance. *European Journal of Applied Physiology*, 109(4), 659–667. <https://doi.org/10.1007/s00421-010-1384-z>