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Investigation of Performance and Subjective Changes in Female Boxers According to the Stages of the Menstrual Cycle: A Prospective Study

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Abstract

This study examines how the performance and physical and psychological state of female boxers change across different phases of their menstrual cycle (MCC). The research question is crucial for sports science and helps improve the performance of female athletes. The hypothesis is that the MCC phases significantly influence female boxers' performance and subjective experiences. Thirty amateur boxers aged 18-35 who had been training and competing consistently for the past 2 years participated in our prospective study. Daily questionnaires were administered, and three distinct phases of the menstrual cycle (follicular, ovulatory, and luteal) were measured. However, analyses were conducted using only follicular and luteal phase data. The ovulatory phase was excluded from the analysis due to its short duration and difficulty in measurement. Parameters such as sleep quality, fatigue, stress, and delayed onset muscle soreness (DOMS) were assessed using the Illinois Agility Test (IAT) and the Hooper Questionnaire. Performance tests were conducted at each cycle phase, and results were compared. Statistical analysis was performed using repeated-measures ANOVA using the SPSS software package. Sleep quality decreased from 2.3 ± 0.5 in the first week to 2.1 ± 0.9 in the fourth week, and fatigue decreased from 3.3 ± 0.6 in the first week to 2.9 ± 0.9 by the end of the fourth week ($p < 0.05$). Mean performance times were 17.3 ± 0.5 seconds in the luteal phase and 17.2 ± 0.5 seconds in the follicular phase, indicating that performance was higher in the follicular phase. Significant changes were also observed in stress and DOMS levels ($p < 0.05$). This study demonstrates that the MC phases significantly influence the performance of female boxers. Performance is particularly high in the follicular phase and low in the luteal phase. These findings suggest that training programs should be tailored to the MC phases of female athletes.

Keywords: Menstrual cycle, Sleep quality, Fatigue, Stress, Delayed onset muscle soreness, Illinois Agility Test

INTRODUCTION

A significant topic of interest in sports science is the influence of the menstrual cycle (MC) on performance and subjective changes among female boxers. The impact of the menstrual cycle on the performance of female athletes is complex and multifaceted. This will help improve the performance of female athletes. Many studies have observed that hormonal fluctuations during the MC have effects on exercise performance, and different phases have different effects on athletic performance. However, recent research has revealed that performance differences between menstrual cycle phases may be insignificant or exhibit individual variation (Carmichael et al., 2021; McNulty et al., 2020). However, some studies have shown an increase in performance during the follicular phase and a decrease in the luteal phase. Furthermore, how hormonal fluctuations affect body temperature, cardiovascular responses, and muscle strength has also been investigated (De Jonge, 2003).

The effects of ovarian hormones on performance have been widely studied. Changes in estrogen and progesterone levels have been shown to influence muscle strength, endurance, and neuromuscular control (Constantini et al., 2005; De Jonge, 2003). Understanding how the different phases of a female boxer's MC affect performance is crucial for sports scientists. The underlying hypothesis is that MC phases can lead to significant differences in female fighters' performance and subjective emotions. Supporting hypotheses include that the follicular phase will lead to better performance, while the luteal phase will be detrimental (Meignié, 2021). Performance parameters include endurance, power, speed, and agility; therefore, changes in these parameters across menstrual cycles will be investigated (Lebrun, 1995).

Most studies designed to assess the impact of the menstrual cycle on sports performance have been conducted across general sports. There are limited studies on specific MC phases among female boxers. Most research focuses on general sports categories, with little information available on high-intensity activities requiring explosive power, such as boxing (Dasa et al., 2021). Research focusing on the impact of the menstrual cycle on explosive sports like boxing is scarce (Dasa et al., 2021; Findlay et al., 2020). Closing this knowledge gap is even more crucial for improving female boxing performance. More details are needed regarding physical fitness during various phases of the menstrual cycle, such as exercise-related fatigue or weakness (Julian et al., 2017).

This study investigates the variations in MC phases on the performance and subjective emotions of female boxers. This research aims to fill a gap in the existing literature and provide findings specific to the sport of boxing. Such data can inform training program design. Furthermore, it can be determined which types of training are most effective at which phases of the cycle to maximize female boxers' performance. These efforts not only improve physical well-being but also promote overall health maintenance among athletes.

METHOD

Research group

Thirty amateur female boxers aged 18–35 years who had been training and competing for the past five years were included in our prospective study. Participants' baseline information was as follows: mean age 24.7 ± 4.1 years, mean BMI 22.4 ± 2.3 kg/m^2. Participants provided informed consent in accordance with the Declaration of Helsinki after reviewing the details of the study plan and the potential pros and cons. A sample size of 30 volunteers was calculated using G*Power software (version 3.1.9.6), with an effect size of 0.3, a power of 0.8, and a probability of error of 0.05. Inclusion criteria were being between the ages of 18 and 35 years, actively training for the past 2 years, and participating in competitions. Participants were selected from women who menstruated naturally. Exclusion criteria included use of hormonal contraceptives or any congenital condition involving the menstrual cycle.

This study was approved by the Mardin Artuklu University Non-Interventional Clinical Research Ethics Committee (Approval Number: 2024/6-29, Date: 11/06/2024). This research was conducted over a nine-week period from October 2024 to December 2024. The first week facilitated adherence to the study protocol. To ensure consistency in schedule and procedures, the study included a clearly defined adaptation week and experimental period. Anonymous online surveys were coded to protect participant anonymity. Participants completed anonymous online surveys to report their menstrual cycles daily throughout the eight-week experimental period. Participant coding ensured that responses and performance tests were from the same individuals. Menstrual cycle phases were calculated based on the average duration of participants' three previous cycles. A researcher-created calendar helped women determine their menstrual cycle phases. To track ovulation timing, participants were asked to measure their basal body temperature each morning upon waking and before engaging in any physical activity. These measurements were taken daily throughout each individual's complete menstrual cycle. A typical temperature rise (approximately 0.3–0.5°C) was considered an indirect indicator of the onset of the luteal phase and ovulation. No other hormones were analyzed in this study, and no blood samples were taken.

Data collection tools

All participants completed a questionnaire each morning upon waking, and phase averages were calculated using the phase stacking method. The “phase overlapping method” is a method of calculating average values by aligning the phases of each participant’s menstrual cycle (Howards et al., 2009). Participants’ performance was assessed using the Illinois Agility Test (IAT) and the Hooper Questionnaire. The IAT was administered before the agility test, and the best value was used for further analysis as reported in the literature. Data were collected daily to calculate the best value for each day as well as the average value for each week throughout the menstrual cycle. The Hooper Questionnaire was used each morning before training to collect subjective information on sleep quality, fatigue, stress, and delayed-onset muscle soreness (DOMS). Each response was given on a 7-point Likert scale, and the Hooper Index was calculated as the sum of the four responses. RPE and sRPE were self-reported by participants after the agility test using the CR-10 Borg scale to measure perceived exertion during training sessions.

Data collection/processing method

RPE was recorded immediately after exercise or 15–30 minutes after the end of the training session, while sRPE was determined as RPE multiplied by training time. Validated questionnaires were used to minimize bias from self-reporting, and reporting times were standardized. The study focused on changes in performance and subjective measurements in the same group of participants across different phases of the menstrual cycle (follicular and luteal).

Data analysis

Statistical analyses were performed using JASP (version 0.14) software. Data distribution was assessed using the Kolmogorov-Smirnov test, assuming normal distribution for all variables. Results are presented as mean values (± standard deviation). Repeated-measures ANOVA was used to determine differences between menstrual cycle phases (follicular and luteal). Bonferroni correction was applied for post-hoc analyses. Statistical significance was set at $p < 0.05$.

FINDINGS

Table 1. Descriptive Characteristics of Participants

Parameter	Mean ± Standard Deviation
Age (years)	24,7 ± 4,1
Height (cm)	165,6 ± 5,3
Body Mass Index (BMI)	22,4 ± 2,3
Body Fat Percentage (%)	24,5 ± 3,2

The descriptive characteristics of the participants in Table 1 show the demographic and anthropometric profiles of the individuals included in the study. Mean age was 24.7 ± 4.1 years, mean height was 165.6 ± 5.3 cm, body mass index was 22.4 ± 2.3, and body fat percentage was 24.5 ± 3.2%.

Table 2. ANOVA Results with Performance and Physiological Parameters (Mean ± SD) According to BMI and Fat Percentage

Parameter	18.5 - 24.9 BMI, < 25% Fat	18.5 - 24.9 BMI, ≥ 25% Fat	25 - 29.9 BMI, < 25% Fat	25 - 29.9 BMI, ≥ 25% Fat	ANOVA Results
Follicular Phase Duration (sec)	17,0 ± 0,4	17,6 ± 0,5	17,5 ± 0,6	17,7 ± 0,5	F(3,26)=4.23, p=0.015*
Luteal Phase Duration (sec)	17,2 ± 0,5	17,6 ± 0,4	17,4 ± 0,5	17,7 ± 0,6	F(3,26)=2.18, p=0.11
Sleep Quality	2,3 ± 0,6	2,1 ± 0,7	2,2 ± 0,8	2,0 ± 0,9	F(3,26)=3.15, p=0.04*
Fatigue	3,3 ± 0,7	3,0 ± 0,8	3,1 ± 0,6	2,9 ± 0,7	F(3,26)=3.78, p=0.02*
Stres	2,2 ± 0,9	1,9 ± 1,0	2,0 ± 1,1	1,7 ± 1,0	F(3,26)=2.94,

					p=0.05
DOMS (Delayed Onset Muscle Soreness)	3,1 ± 0,8	2,7 ± 0,7	2,9 ± 0,9	2,4 ± 0,6	F(3,26)=4.05, p=0.01*
Hooper Index	10,7 ± 2,2	10,0 ± 2,4	10,3 ± 2,5	9,5 ± 2,3	F(3,26)=3.50, p=0.03*
Perceived Exertion (RPE)	6,0 ± 0,4	6,1 ± 0,5	5,9 ± 0,6	6,0 ± 0,7	F(3,26)=1.12, p=0.35
Session Difficulty Score (sRPE)	462,5 ± 29,0	455,0 ± 30,2	448,3 ± 40,5	435,0 ± 50,1	F(3,26)=2.45, p=0.08

In the follicular phase, the group with a BMI of 18.5-24.9 and a body fat percentage of <25% had the best agility performance with an average of 17.0 ± 0.4 seconds. Times in the other groups ranged from 17.5 to 17.7 seconds. Group differences in follicular phase performance were found to be statistically significant (F(3,26)=4.23, p=0.015). In the luteal phase, times ranged from 17.2 ± 0.5 to 17.7 ± 0.6 seconds, and the difference was not significant (F(3,26)=2.18, p=0.11).

Physiological load indicators; There were significant differences between the groups in terms of sleep quality (2.3 ± 0.6 vs. 2.0 ± 0.9; F(3,26)=3.15, p=0.04), fatigue (3.3 ± 0.7 vs. 2.9 ± 0.7; F(3,26)=3.78, p=0.02), DOMS (3.1 ± 0.8 vs. 2.4 ± 0.6; F(3,26)=4.05, p=0.01) and Hooper Index (10.7 ± 2.2 vs. 9.5 ± 2.3; F(3,26)=3.50, p=0.03). Perceived exertion scores (RPE: 6.0 ± 0.4 vs. 6.1 ± 0.5; sRPE: 462.5 ± 29.0 vs. 435.0 ± 50.1) were not statistically different between the groups (p>0.05).

These results indicate that body composition influences performance and recovery parameters during the follicular phase of the menstrual cycle, while this effect diminishes during the luteal phase. It was concluded that perceived training exertion was perceived at similar levels regardless of body composition.

Table 3. Performance and Subjective Measurement Values According to Menstrual Cycle Phases (n = 30)

Parameter	Follicular Phase (Mean ± SD)	Luteal Phase (Mean ± SD)	F	p	η^2
Illinois Agility Time (sec)	17.2 ± 0.5	17.3 ± 0.5	5.12	0.031*	0.15
Sleep Quality (Hooper)	2.3 ± 0.5	2.1 ± 0.9	4.25	0.046*	0.12
Fatigue (Hooper)	3.3 ± 0.6	2.9 ± 0.9	5.88	0.021*	0.17
Stress (Hooper)	2.2 ± 0.9	1.8 ± 1.0	4.90	0.034*	0.14
DOMS (Muscle Soreness, Hooper)	3.1 ± 0.8	2.3 ± 0.7	8.03	0.008**	0.22
Perceived Exertion (RPE)	6.0 ± 0.3	6.0 ± 0.6	4.85	0.004**	0.12
Session Difficulty Score (sRPE)	462.5 ± 28.1	430.2 ± 72.2	6.21	0.001**	0.18

* p < 0.05 significant difference, **p < 0.01 highly significant difference

As seen in Table 3, statistically significant differences were found in the performance and subjective responses of female boxers between the follicular and luteal phases. Illinois Agility Time increased from 17.2 ± 0.5 seconds in the follicular phase to 17.3 ± 0.5 seconds in the luteal phase, and this difference was found to be significant as a result of repeated measures ANOVA ($F(1,29) = 5.12$, $p = 0.031$, $\eta^2 = 0.15$). Significant decreases were observed in the luteal phase in the Hooper Index components of sleep quality (follicular: 2.3 ± 0.5; luteal: 2.1 ± 0.9; $p = 0.046$), fatigue (3.3 ± 0.6 vs. 2.9 ± 0.9; $p = 0.021$), stress (2.2 ± 0.9 vs. 1.8 ± 1.0; $p = 0.034$) and DOMS (3.1 ± 0.8 vs. 2.3 ± 0.7; $p = 0.008$).

Similarly, although the perceived exertion (RPE) value remained constant at 6.0 ± 0.3 in the follicular phase and 6.0 ± 0.6 in the luteal phase, it showed a significant difference with the weekday distribution ($F(3,87) = 4.85$, $p = 0.004$). The session exertion score (sRPE) decreased from 462.5 ± 28.1 in the follicular phase to 430.2 ± 72.2 in the luteal phase, and this difference was found to be statistically significant ($F(3,87) = 6.21$, $p = 0.001$).

These findings demonstrate that menstrual cycle phases have significant effects on both the physical performance and subjective well-being of female athletes. It is particularly noteworthy that agility performance is better in the follicular phase, while physiological load indicators such as fatigue and muscle soreness are reduced in the luteal phase.

DISCUSSION AND CONCLUSION

The results of this study are similar to those of McNamara et al., who investigated the relationship between menstrual cycle phases and performance in female athletes. McNamara and his team determined that cycle phases lead to different performance (McNamara et al., 2022). According to a meta-analysis by Nuria Gimenez-Blasi and colleagues (2022), menstrual cycle phases were found to affect performance and metabolism in athletes (Gimenez-Blasi et al., 2022). Kelly, L. McNulty, and their team (2020) investigated the effects of cycle phases on exercise performance in eumenorrheic women and reported that exercise performance was generally higher in the follicular phase and lower in the luteal phase (McNulty et al., 2020). These findings, as described in our study, indicate that menstrual cycle phase has a significant impact on athletes.

Our study observed higher performance during the follicular phase. This result is consistent with previous studies demonstrating increased muscle strength and endurance during the follicular phase, when estrogen levels are higher (Bruinvels et al., 2022). However, it is important to note that this relationship cannot be definitively confirmed because we did not directly measure hormone levels in this study.

Additionally, recent research by Georgie Bruinvels and colleagues (2022) highlights the importance of monitoring daily hormonal changes, particularly during transitions between menstrual cycle phases. This approach is crucial for understanding the full impact of the menstrual cycle on athletic performance and developing nonpharmacological strategies to alleviate negative symptoms (Bruinvels et al., 2022).

The results of this study showed that follicular phase durations among female boxers varied between 17.0 seconds and 17.7 seconds across different groups regarding BMI and body fat percentage. A study by Schulze et al. (2020) analyzed data on demographic and performance data for female athletes according to the menstrual cycle, and found that the phase of the menstrual cycle had a significant effect on body fat percentage and BMI measurements (Schulze et al., 2021). Furthermore, Cavedon et al. (2018) analyzed the effects of BMI and body fat percentage on performance in female handball players and showed that these parameters exerted a significant influence by influencing performance time. For example, longer performance times were observed in users with a higher body fat percentage (Cavedon et al., 2018).

This study is particularly relevant for values related to sleep quality, fatigue, stress, and delay-induced muscle soreness (DOMS). The study by Nobari et al. (2021) used the Hooper Index (HI) to investigate changes in these parameters at different weekly intervals for young wrestlers during preparation (18). Based on our study, significant differences in the Hooper Index parameters were identified during different menstrual cycle phases, which may indicate hormonal influence on sleep, fatigue, and stress levels. Sleep quality improved by 2.3 ± 0.5 in the first week and decreased to 2.1 ± 0.9 by the end of the fourth week. Fatigue values similarly decreased from 3.3 ± 0.6 in the first week to 2.9 ± 0.9 in the fourth week. Thorpe et al., in their study on elite football players, showed a significant decrease in sleep quality and a 35–40% increase in fatigue scores the day after a match (Thorpe et al., 2016). In another study by Nobari et al. (2021), fatigue and DOMS values, as well as stress, showed statistically significant changes throughout the season in youth soccer players (Nobari et al., 2021). Similar changes in these parameters were observed across the selected studies, suggesting that training programs should consider menstrual cycle phases to optimize performance.

There are several issues regarding the impact of the menstrual cycle on female boxing performance. Problems such as irregular menstruation and heavy bleeding are common among female athletes and have been found to reduce quality of life (Von Rosen et al., 2023). These issues should be addressed widely, as current data suggest that awareness and support of the menstrual cycle in female athletes remains inadequate (Findlay et al., 2020). Future research on the impact of menstrual cycle phases on the performance and quality of life of female athletes is recommended (Brown and Knight, 2022). Additionally, it is important to gain more insight into the clinical indicators of athletes experiencing these issues so that their training and competition can be optimized and their health can be maintained (Brown et al., 2022).

These findings pertain to the first four weeks of the total 8-week data collection period. Data validation and reprocessing were conducted within the last four weeks.

The most important conclusion of this study is that female boxers exhibit significant performance changes depending on the phases of their menstrual cycle. A significant relationship was found between the menstrual cycle and performance of the 30 licensed amateur boxers who participated in the study. According to the Illinois Agility Test (IAT), the mean performance time, based on the phases of the menstrual cycle, was 17.2 ± 0.5 seconds in the follicular phase and 17.3 ± 0.5 seconds in the luteal phase. This difference was statistically significant ($p <0.05$).

As seen in Table 3, weekly changes were observed in the hooper index parameters. In the first week, mean sleep quality was 2.3 ± 0.5, fatigue was 3.3 ± 0.6, stress was 2.2 ± 0.9, and DOMS was 3.1 ± 0.8. a decrease in the hooper index for these parameters was observed as sleep quality decreased to 2.1 ± 0.9, fatigue to 2.9 ± 0.9, stress to 1.8 ± 1.0, and doms to 2.3 ± 0.7. these changes were statistically significant ($p < 0.05$). Significant differences were also observed in RPE and SRPE values. RPE was 6.0 ± 0.3 in the first week and 6.0 ± 0.6 in the fourth week ($p < 0.05$). srpe values decreased from 462.5 ± 28.1 in the first week to 430.2 ± 72.2 in the fourth week ($p < 0.05$).

Recommendations

Our study has several limitations. First, the small number of participants (n = 30) may limit the generalizability of the findings. Second, the lack of hormonal measures precluded the precise determination of menstrual cycle phases. Finally, the study was relatively short-term. Furthermore, hormone-assessed or biphasic cycles were not used, which may make it difficult to predict the full extent of hormonal changes that occur during the menstrual cycle. Because of the short duration of this study, longer-term menstrual cycle phases may best define the results.

Further detailed research with larger sample sizes, including hormone measurements, is recommended. Investigating the impact of the menstrual cycle on different sports would also be of practical importance. More research on the impact of menstrual cycle phases should be conducted to improve performance and quality of life across various sports over time. This would allow subjective data to be supplemented with objective data, such as hormone testing, providing a broader understanding of how female athletes' menstrual cycles impact their performance.

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CONTRIBUTION RATE	***EXPLANATION***	***CONTRIBUTORS***
Idea or Notion	*Form the research hypothesis or idea*	Mine Akkus Ucar
Design	*To design the method and research design.*	Mine Akkus Ucar
Literature Review	*Review the literature required for the study*	Mine Akkus Ucar
Data Collecting and Processing	*Collecting, organizing and reporting data*	Mine Akkus Ucar
Discussion and Commentary	*Evaluation of the obtained finding*	Mine Akkus Ucar
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