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Differences in perceived readiness to train between two menstrual cycle phases in female athletes

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Abstract

Background: The menstrual cycle and associated physical symptoms, such as fatigue, mood swings, cramps, changes in energy levels, and physical discomfort, may directly influence athletic performance.
Aims: The purpose of this study was to determine the effects of two stages of the menstrual cycle (early follicular & luteal phases) on recovery from exercise, as measured by heart rate variability, jumping performance, and a psychological wellness questionnaire in conjunction with current training regimes.
Methods: A repeated measurement design was utilized, and statistical significance was set a priori at $p < 0.05$. Fifteen (n = 15) female participants (mean ± SD) for age, height, weight, body composition of 19.60 ± 1.3 years, 164.67 ± 5.78 cm, 62.44 ± 10.95 kg, and body composition 24.34 ± 6.45%), were tested in the early follicular and early luteal phase of their menstrual cycle.
Results: Researchers observed significant differences in perceived readiness to train between the two phases. The early luteal phase showed a significantly higher ($p < 0.01$) score on the wellness questionnaire than the early follicular phase. No significant differences were found for HRV ($p = 0.62$), reactive strength index ($p = 0.59$), and vertical jump performance ($p = 0.12$) between the two phases.
Conclusion: These results suggest that in the early luteal phase, athletes are less negatively affected by psychological factors and appear better prepared to train. However, these factors do not have a significant impact on performance metrics.

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INTRODUCTION

During the 2016 Rio Olympics, women made up 45% of the 11,444 athletes, marking a major milestone in sports participation (de Borja et al., 2022). This progress continued into the 2024 Paris Olympics, where full gender equality was achieved in 28 out of 32 sports (Bach, 2024). The increase in women's sports participation has boosted interest in activities such as women's soccer, as evidenced by higher TV ratings, attendance, and publicity. FIFA projects the number of female soccer players will grow from 13.3 million in 2019 to 60 million by 2026 (Randell et al., 2021). Additionally, international goals focusing on promoting health and wellness through exercise and sport are continuing to gain popularity and will further add to increases in participation (Temm et al., 2022).

This growth in women's sports underscores the need for further research into women-specific aspects of sports science. Physiological, anatomical, and biomechanical differences between men and women stem from genetic and hormonal factors. While women generally perform differently from men, especially in strength and power events, they can have an advantage over their male counterparts in other areas, such as flexibility (Brügger, 2023). As Female Participation increases ongoing research is essential to understand differences in body composition and physiology, as well as the impact of the menstrual cycle on training and performance (Bernstein & Behringer, 2023). Existing studies have yielded mixed results on how different menstrual cycle phases influence athletic readiness and

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performance, underscoring the need for further research. While prior research has often concentrated on either physiological outputs or self-reported symptoms, this study aims to measure both in well-trained athletes. In doing so, the outcomes may provide a more holistic understanding of how different MC phases affect readiness to train and athletic performance. The main goal of this study is to offer athletes and coaches practical, evidence-based insights for tailoring training programs in an effort to reduce injury risk and enhance performance.

In the sport science field, the term readiness to train refers to an athlete's state of balance between their current training load, fatigue, and the potential risk of injury or illness (Janetzki et al., 2023). Practitioners may use multiple parameters to provide a comprehensive, holistic understanding of an athlete's training preparedness, accounting for daily, weekly, or monthly performance fluctuations (Janetzki et al., 2023). The primary goal is to quantify physiological and psychological loads and prevent non-functional overreaching or overtraining while optimizing performance or training by either reducing, maintaining, or increasing training parameters (Jones et al., 2017). According to Temm et al. (2022), the MC is often overlooked as a key parameter that may severely affect performance.

The menstrual cycle (MC) has two phases: the follicular phase (days 1-13) and the luteal phase (days 14-28). The follicular phase, which starts with menstruation and ends before ovulation, is marked by lower hormone levels and developing ovarian follicles. During this phase, the body typically experiences a decrease in resting core body temperature and increased parasympathetic activity. The luteal phase follows, with increased progesterone and estrogen, which boost sympathetic activity in preparation for a potential pregnancy. For the current research project, the early follicular and early luteal phases were selected because of their distinct hormonal characteristics, which may have performance implications. Researchers have examined MC's impact on athletic performance with mixed results (Thiyagarajan et al., 2024). McNulty et al. (2020) found decreased performance during the early follicular phase (EFP) due to lower estrogen. Carmichael et al. (2021) observed higher motor unit firing rates and testosterone levels in the late luteal phase. Despite mixed findings on performance differences across phases, some studies suggest varying effects on muscle strength and hypertrophy. Advancements in AI and wearable technology may help better manage MC phases related to performance, but further research is needed.

McNulty et al. (2020) noted that exercise performance may be reduced during the EFP as compared to other phases in the MC. Differences might be more or less pronounced depending on the population (e.g., elite athletes vs. recreational athletes). Niering et al. (2024) reviewed 22 studies and found that strength was significantly reduced in the EFP when compared to the early luteal phase (ELP). Researchers also found that peak isometric force increased significantly in the late follicular phase, while isokinetic strength was elevated during ovulation. The authors concluded that the late follicular phase appears to be the optimal time for achieving peak dynamic strength, a finding they attribute to elevated estrogen levels. Conversely, the late luteal phase may negatively impact strength, possibly due to increased muscle fatigue, lower estrogen levels, and higher progesterone levels, leading to reduced maximum force output.

On the other hand, Colenso-Semple et al. (2023) suggest that MC does not negatively influence exercise performance. The researchers suggest that most investigations observing significant differences in exercise performance pose several methodological concerns. Papers in which the researchers deemed moderate to high quality, 90% did not find any significant differences in exercise performance. Studies deemed low quality include a small sample size, no difference between contraceptive and non-contraceptive users, and no heterogeneity (Colenso-Semple et al., 2023). According to Nolan et al. (2024), while one might theorize that menstrual symptoms such as bleeding and cramps could negatively affect training outcomes, their findings showed no significant differences in skeletal muscle hypertrophy, power, or strength adaptations between contraceptive and non-contraceptive users over the 12-month training period.

Several studies have examined differences in objective performance measures across the MC, but few have examined both objective and subjective measures concurrently (Carmichael, 2021). Therefore, the purpose of this study is to add to the growing body of knowledge regarding the MC and athletic performance, specifically, the researchers aim to determine the potential differences between two stages of the menstrual cycle (early follicular & early luteal phase) on measures of readiness and performance in National Collegiate Athletic Association (NCAA) Division II female athletes. Unlike previous studies that have focused on either physiological or self-reported outcomes, this investigation integrates both to provide a more comprehensive understanding of how menstrual phases may influence readiness and performance in trained female athletes. Providing this fast-growing population with research, such as the proposed, is critical for advancing evidence-based coaching strategies.

METHOD

Research Design

To examine the effects of two specific stages of the MC (early follicular & early luteal phases) on performance and readiness, a repeated-measures design was used. Female NCAA Division II athletes were recruited as part of their regular sport training to perform two identical strength training (ST) sessions during different phases of the MC. One session took place during the early follicular phase (days 1-7) and the second in the early luteal phase (days 14 to 21).

Participants

Fifteen (n = 15) NCAA Division II athletes from various sports, including track & field, cross country, softball, and cycling, volunteered for the study and completed all data collection procedures. All data were collected during the off-season training period for each athlete and sport. While specific training load was not measured, the NCAA guidelines allow for athletes in the off-season period to train for a total of 8 hours per week over 5 days. The inclusion criteria for this study were: 1) NCAA Division II athletes, 2) 18-26 years of age, 3) experiencing a regular MC, 4) cleared by the athletic department and deemed healthy based on the medical questionnaire, 5) could follow verbal directions, and 6) were not pregnant or breastfeeding.

Participants were also screened to include those without 1) musculoskeletal injuries within the previous 30 days that limited the ability to train for longer than 3 days, 2) known cardiovascular issues that may have affected heart rate variability or the safety of following an exercise prescription, 3) consumption of any drugs or illegal substances including tobacco, and 4) consumption of caffeine 24 hours prior the testing. The University's Institutional Review Board approved all data collection procedures.

After signing informed consent, participants completed identical two ST training sessions, one in the early follicular phase (days 1 to 7) and the other in the early luteal phase (days 14 to 21). Each ST session was performed in conjunction with the participants' regular strength and conditioning program, with the exercise selection, volume, and intensity determined by each participant's coach. Due to the individual nature of the study, it was not possible to standardize strength sessions across athletes of multiple sports; therefore, researchers analyzed the differences in pre and post-measurements to control for differences in ST sessions. Participants were familiarized with the chosen exercises of the ST session and had completed them at least once before completing the session. Although nutrition was not controlled, participants were instructed to maintain normal dietary habits throughout the study. Anthropometric measures, including height (cm), weight (kg), and body composition (%BF) (Seca mBCA 554, GmbH. Hamburg, Germany), were measured before the first ST session. ST sessions were performed at the same time of day for both trials, with participants instructed to maintain normal sleep and nutritional patterns throughout the study.

Instruments

Heart Rate Variability

To better understand autonomic nervous system balance across the two MC phases, researchers measured heart rate variability (HRV) (Gullett et al., 2023). HRV measurements were captured with a portable Scosche Rhythm heart rate sensor for 10-15 minutes. Before each ST session, use the Elite HRV smartphone application for analysis. This application and method of data collection have been found valid and reliable (Vondrasek et al., 2023). HRV measurements were taken in a seated position for 180 seconds, with participants maintaining a breathing rate of 12 breaths/min and performing no other activities during the recording. For all HRV collection participants, a quiet room was used to minimize distractions. HRV score was calculated as the natural log of the root mean square of successive differences (RMSSD). Scores were then scaled to fit in a 0 to 100 range for analysis. To determine the autonomic response to each ST session, HRV measures were taken 10-15 minutes. Before and immediately following each ST session.

Jumping Performance

To evaluate jumping performance, researchers used a Skyhook contact mat (RDM, Florida, USA) that measures flight time and ground contact time. To measure lower-body power and neuromuscular performance, each participant performed two sets of four consecutive maximal countermovement jumps with 30 seconds of rest between sets (Ramirez-Campillo et al., 2023). Jumps were performed following the warm-up for each session, and immediately following the completion of each ST session. During the jumps, participants were instructed to place their hands on their hips and to jump as high and as fast as possible. Reactive strength index (RSI) was calculated as jump height divided by ground contact time, and the highest RSI across the two trials was selected for further analysis. The highest jump height (cm) of the two trials was recorded as vertical jump (VJ) for further study.

Wellness Questionnaire

The wellness questionnaire (WQ) used in this study was developed by McGahan et al. (2020) and validated by Herman et al. (2006). The purpose of the WQ is to assess the athlete's readiness to train by evaluating mood state, sleep quality, energy levels, muscle soreness, diet, and stress levels. This particular WQ uses a 1-5 scoring system for each question, with lower scores indicating higher perceived stress or suboptimal readiness, and higher scores indicating lower perceived stress or greater readiness to train. Participants completed the WQ following HRV collection for each trial. Answers for each question were added together, giving the participant a total score between 6 and 30. The complete WQ is shown in Table 1.

Table 1. Wellness Questionnaire

Category	1	2	3	4	5
Mood State	Highly annoyed/irritable/down	Snappiness with teammates, family, and co-workers	Less interested in others/activities than usual	Good mood	Very positive mood
Sleep Quality	Hardly slept at all	Tossed and turned	Reasonable/Just OK	Good night's sleep; Feeling refreshed	Had a great sleep. Feeling very refreshed
Energy Levels	Very lethargic – no energy at all	Very low energy levels	Reasonable energy levels	Good energy levels	Full of energy
Muscle Soreness	Extremely sore	Very sore	Quite sore	Mild soreness	Not sore at all
Diet yesterday	All meals are high sugar/processed food, no fruit/veg	Some meals are high in sugar/processed food, no fruit & veg	Ate reasonably, some sugar/processed food intake, at least one serving of veg	Ate well, low sugar/processed food intake, two or more servings of veg & fruit	Ate really well, no added sugar/processed foods, and lots of veg and some fruit
Stress	Highly stressed	Feeling stressed	Reasonable / Just OK	Relaxed	Very relaxed

Note. The WQ assesses the athlete's readiness by evaluating mood state, sleep quality, energy levels, muscle soreness, diet from the previous day, and stress levels, using a scale from 1 to 5.

Analysis Plan

Statistical analysis was conducted using SPSS Statistics Software. General descriptive statistics were reported (mean ± standard deviation), and a multivariate analysis of variance (MANOVA) was performed to assess potential differences in the measured parameters between the two phases of the MC. A Tukey's HSD post-hoc analysis was used to determine specific differences amongst the measured variables. Statistical significance was set a priori at $p < 0.05$.

RESULTS AND DISCUSSION

Result

A total of 15 participants completed all required procedures for the study. General statistical descriptive data, including age, height, weight, and body composition, are presented below. Anthropometric variables, including the mean & standard deviation, are presented in Table 2.

Table 2. *Descriptive Characteristics of Participants*

Characteristics (n = 15)	Value	Minimum	Maximum
Age (yrs)	19.60 ± 1.3	18	22
Height (cm)	164.67 ± 5.78	159.70	172.72
Weight (kg)	62.44 ± 10.95	51.94	81.33
Body Composition (bf%)	24.34 ± 6.46	14.3	36.2

Note. All participants were female. Values are presented as mean ± SD; Age – years, Height – centimeters; Weight – kilograms, Body Composition – Body Fat %.

Changes in HRV were assessed immediately before and after each ST session in both trials. No statistically significant differences ($p = 0.61$) were observed in HRV changes between the two phases. Additionally, no statistically significant differences were observed in jumping performance, as measured by jump height and RSI. Jump height, measured pre and post ST session, saw a decrease of 1.27 cm in the EFP post and 1.69 cm in the ELP post measures, resulting in a nonsignificant ($p = 0.12$) difference between the two trials. RSI also resulted in no significant difference ($p = 0.59$) between the EFP post and the ELP post values in the measured participants. Significant differences ($p < 0.01$) were observed in the WQ scores between the EFP and ELP, as seen in Figure 1. These results indicate significantly lower readiness to train in the EFP than in the ELP. Mean ± SD for HRV, jump height, RSI, and WQ can be seen in Table 3.

Table 3. *Pre and Post Measured Values of Performance & Readiness*

n = 15	EFP Pre	EFP Post	ELP Pre	ELP Post	*p*-value
Heart Rate Variability (au)	71.13 ± 4.97 (7%)	70.47 ± 5.89 (8%)	71.40 ± 6.17 (9%)	69.07 ± 5.96 (9%)	0.61
Reactive Strength Index (jump height/contact time)	2.47 ± 0.60 (24%)	2.40 ± 0.55 (23%)	2.55 ± 0.78 (31%)	2.42 ± 0.65 (27%)	0.59
Jump Height (cm)	31.61 ± 6.54 (21%)	30.34 ± 7.79 (26%)	33.26 ± 6.50 (20%)	31.57 ± 6.47 (20%)	0.12
Wellness Questionnaire (au, scale 6-30)	19.00 ± 2.62* (14%)		22.67 ± 2.35 (10%)		< 0.01

Note. EFP = Early Follicular Phase, ELP = Early Luteal Phase. Values are presented as mean ± SD (% Coefficient of Variance). * denotes significantly different ($p < 0.01$) from EL Pre.

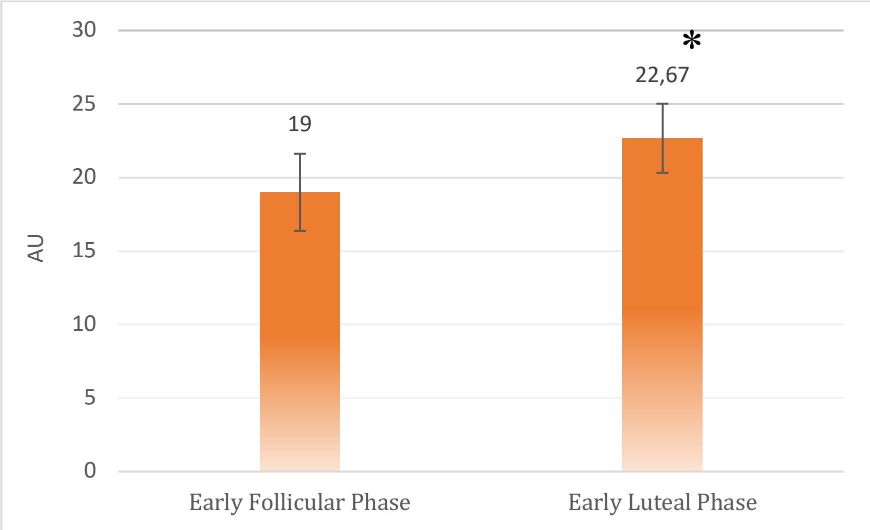

Figure 1. *Wellness Questionnaire Response for Each Phase*
Note. * denotes significantly higher than Early Follicular Phase ($p < 0.01$). Questionnaire scale = 6-30.

Discussios

Implications

This study aimed to determine the potential effects of hormonal fluctuations during the MC following a single strength-training session. It was designed as a practical, applied investigation seeking to gain insight into how hormonal fluctuations during the MC may influence female athletic performance. When comparing the EFP (day 1-7) and the ELP (day 14-21), no significant differences were observed in HRV or jumping performance; however, significant differences were observed in readiness to train, as measured by wellness questionnaire responses, between the two MC phases. The opposing physiological effects of estrogen and progesterone may partly explain these findings. During the EFP, both hormones remain low, leading to reduced glycogen storage, lower plasma volume, and potential decrements in thermoregulation. In contrast, the ELP, characterized by elevated progesterone, may increase core temperature, ventilation, and perceived exertion. Despite these hormonal differences, our results showed no significant changes in performance, possibly because the athletes' training status mitigated the effects of hormones on acute performance (Isola et al., 2024).

Results from the study based solely on performance measurements suggest that training regimens may not need to be adjusted by menstrual phase. However, our study highlights the potential impact on psychological readiness and the consideration of mood & energy levels before training. The results of this investigation align with those of similar research projects. For example, Brown et al. (2021) found that women often report multiple symptoms (fatigue, mood swings, cramps, changes in energy levels, and physical discomfort) and that these symptoms can have a direct influence on training or competitive outcomes. Another investigation by Armour et al. (2020) indicated that 74.4% of athletes reported a normal MC, with 83.2 % reporting premenstrual symptoms like breast tenderness, headaches, and mood swings. Additionally, 66.4% experienced significant discomfort on the first day of their MC. Numerous articles suggest that discomfort experienced during the MC may directly influence athletic performance and play a contributing factor in the occurrence of injuries (Bernstein & Behringer, 2023; Carmichael et al., 2021; Feuerbacher et al., 2023; McNulty et al., 2020; Nakamura et al., 2011). A study conducted by Rocha-Rodriguez et al. (2021) reveals that approximately 75% of female athletes experience adverse effects, such as changes in body temperature, fluid regulation, and increased risk of injuries related to hormonal changes during the MC. Similar results were reported by Findlay et al. (2020), who analyzed the effects of the MC on athletic performance in 15 international female rugby players and found that 93% of participants experienced MC-related symptoms, with two-thirds reporting that these symptoms negatively impacted their athletic performance.

Our findings on performance and HRV align with prior research indicating no performance differences across various phases of the menstrual cycle (MC) (Findlay et al., 2023). For example, Colenso-Semple et al. (2023) reviewed several meta-analyses and found limited evidence on MC phase effects in resistance training. Similarly, Dasa et al. (2021) reported no performance differences between the follicular and luteal phases of the MC. Mattu et al. (2019) also found no significant changes in aerobic performance across phases, though perceived performance was higher in the mid-follicular phase. Hunter (2014) concluded there is no definitive link between hormonal fluctuations and fatigue, recovery, or performance. De Borja et al. (2022) similarly found that the mechanisms underlying any MC impact on high-level performance remain unclear. Overall, research shows no consensus, and in this cohort, the MC does not appear to influence athletic performance or readiness to train. The absence of significant differences in HRV or CMJ across phases suggests that neuromuscular efficiency and autonomic balance are not affected by hormonal fluctuations in trained athletes. While estrogen has been associated with enhanced neuromuscular transmission and faster muscle repair through its antioxidative and membrane-stabilizing effects, progesterone may counteract some of these benefits by promoting catabolic enzyme activity and increasing muscle relaxation times (Johnson et al., 2023).

While many researchers have found no differences across the MC, some research suggests performance may be affected. For example, Sung et al. (2014) observed greater improvements in muscular strength and mass following a 4-month strength-training protocol in the follicular phase than in the luteal phase. Schlie et al. (2025) conclude that submaximal performance, neuromuscular coordination, and agility are all influenced by the MC cycle. For example, peak performance values in the early follicular phase are significantly lower than in the luteal phase. According to the authors, maximum strength and explosive strength do not appear to be influenced by the phases of the MC cycle. In one study, the researchers reported lower CMJ jump performance in the early follicular phase than in the other phases. In team sports, it is fascinating that mobility is significantly higher in the luteal phase, immediately after ovulation (Schlie et al., 2025).

Discrepancies in the literature highlight the need for further research to clarify the effects of hormonal changes on female athletes' performance. Several methodological considerations could potentially lead to discrepancies in evidence regarding the effect of the MC on athletic performance. These factors include accurate verification of the specific MC phases, accounting for hormonal variations concentrations (such as progesterone & estrogen levels), and mitigating potential methodological issues related to study design and participant selection. Addressing these factors may help to improve future research and identify specific mechanisms of action. Colenso-Semple et al. (2023) support these findings and highlight that inter-individual differences in cycle and phase lengths likely influence research on the MC and performance. Solli (2020) notes that MC length is highly individualized, with variations of up to 8 days, and that the duration of each specific phase can also fluctuate considerably. Future research should focus on exploring the long-term effects of the MC on athletic performance and developing simple, valid, and reliable methods for practitioners to determine MC phases and adjust training programs accordingly based on the MC's effects on training readiness. In summary, this study contributes to the growing body of evidence suggesting that individual responses may vary widely and that more robust, personalized training approaches during the MC may be key to optimizing athletic performance in female athletes.

Research Contribution

This project contributes to the field of sports science by deepening the understanding of how the MC can influence a female athlete's readiness to train. Unlike previous studies, which focused solely on physiological metrics or subjective perceptions, this study integrates both objective (HRV and RSI) and subjective (WQ) measures. The findings suggest that emotional and psychological factors, rather than physiological ones alone, play a crucial role in perceived training preparedness. By emphasizing a holistic approach to athlete monitoring, the research provides evidence-based insights for coaches to consider menstrual cycle-related fluctuations when tailoring training programs, ultimately promoting more optimal coaching strategies for female athletes.

Limitations

The researchers acknowledge that this study has potential limitations, including a small sample size of 15 participants. Further research with a larger sample size is recommended to identify and support our findings. The chosen strength training sessions were not standardized, but were conducted in conjunction with their current strength training regimes. Specific exercises and intensity/volume approaches may have varied among participants, making it difficult to compare results across sports. Different athletes within the same sport may have varying training backgrounds and experience. This variability could have influenced the outcomes. The age of participants was controlled, but older & more experienced athletes may have responded differently to the training regimes (beginner vs. advanced). Researchers used participants' knowledge of their menstrual cycle start date to determine MC phases. Individual variations in start day may have led some individuals to be measured outside the desired MC phase.

Suggestions

These findings highlight that perceived fatigue or reduced recovery may not be solely dictated by physiological markers such as performance. Instead, psycho-emotional factors, intrinsically linked to the MC, can significantly contribute to an athlete's subjective experience of fatigue. The ability to recognize the multifactorial nature of recovery, which can be influenced by training load, nutrition, sleep, and individual variability, is paramount for effective training periodization and recovery strategies. A singular "magic bullet" for fatigue monitoring throughout the MC is yet to be identified. Rather, a comprehensive approach employing a suite of methods, applied with regularity and interpreted in conjunction, offers the most robust pathway to enhancing athlete safety and optimizing performance. Future studies may focus on practical applications in the field of play over a long period of time and consider individual athlete characteristics.

CONCLUSION

While based on a small sample, our findings align with a growing body of research that highlights the multifaceted influence of the menstrual cycle on female athletes. These results contribute to the evolving discussion on how best to support athletes through a holistic approach that considers not only physical but also psychological and emotional factors. For coaches and sport scientists, a critical and often underestimated factor lies in the interplay between the MC and an athlete's psychological and emotional training-readiness state. Our research underscores the significant psychological impact of the MC on athletic performance, suggesting that a one-size-fits-all training approach is insufficient. These results align with previous research, which finds that symptoms such as fatigue and mood swings in the early follicular phase can be directly linked to performance outcomes.

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AUTHOR CONTRIBUTION STATEMENT

N.R. conceived the study, performed the experiments, and wrote the manuscript. B.C. contributed to the data analysis and interpretation, supervised the project, and reviewed the manuscript.

AI DISCLOSURE STATEMENT

The authors declare that this research was prepared, researched, written, and edited without the aid of artificial intelligence (AI) techniques.

CONFLICTS OF INTEREST

The authors confirm that there are no conflicts of interest that could influence the conduct of this study, the analysis of data, the preparation of the manuscript, or its publication.

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