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# Training performance variations across menstrual cycle phases in female athletes and current approaches

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**Abstract**

This review examines variations in training performance across menstrual cycle phases in female athletes in light of current evidence and offers practice-oriented recommendations. Fluctuations in estrogen and progesterone during the menstrual, follicular, ovulatory, and luteal phases may influence energy metabolism, neuromuscular control, thermoregulation, pain perception, and recovery processes; however, performance outcomes appear heterogeneous due to individual differences and methodological variability. Evidence suggests greater readiness for strength, power, and technical skills in the follicular phase; short-term advantages in coordination and speed around ovulation; and increased thermal strain, perceived exertion, and hydration demands in the luteal phase. Major sources of inconsistency in the literature include differences in phase verification methods, limited sample sizes, insufficient control of contraceptive use, and heterogeneity in testing schedules and environmental conditions. From an applied standpoint, integrating phase-aware and individualized load–recovery planning with nutrition and hydration strategies and symptom management protocols is recommended. Future research should prioritize standardized phase verification, sport-specific comparative designs, longitudinal monitoring, and multimodal data integration via wearable technologies to advance hormone-informed personalized periodization approaches

**Keywords:** Menstrual cycle; female athletes; training performance

## INTRODUCTION

The increase in the number of female athletes has reopened debate in sports science on a long-neglected topic: the determinant role of female physiology in training planning. Most existing models of athletic performance have historically been based on male physiology; consequently, biological variables specific to the hormonal cycles of female athletes have often been adapted to generic training regimens. However, the menstrual cycle is a multidimensional process that influences a broad biological spectrum, ranging from energy production and muscle tissue adaptation to neuromuscular coordination and thermoregulation (Oosthuyse et al., 2022; Akkuş-Uçar, 2024). Therefore, the physiological response to training loads in female athletes may differ significantly depending on the phase of hormonal changes.

The menstrual cycle is typically conceptualized in four main phases: menstrual, follicular, ovulatory, and luteal. During these phases, estrogen and progesterone levels are secreted at varying rates, shaping the organism's metabolic, neuromuscular, and psychological responses. While positive stimuli for muscle strength, endurance, and neuromuscular coordination emerge during the follicular phase, characterized by rising estrogen, the luteal phase, dominated by progesterone, may negatively impact performance due to increased body temperature, impaired hydration balance, and heightened perceived exertion (Bruinvels et al., 2022). These distinctions manifest not only at the level of energy metabolism but also in post-training recovery processes. Factors such as muscle glycogen replenishment, pain threshold, and sleep quality are also suggested to be closely associated with hormonal fluctuations (Kissow et al., 2022). However, research on the effects of menstrual cycle phases on performance has not yielded consistent results. Some studies have reported that phase-based training planning provides positive effects on muscle strength and hypertrophy (Kissow et al., 2022), whereas other studies have shown that training performed in different phases does not create a significant difference in performance determinants (Taylor et al., 2024). One of the main reasons for these inconsistencies lies in the variation of phase verification methods used across studies. While some studies determine the phase based on participant self-report using the calendar method, others employ luteinizing hormone tests or serum hormone measurements. This methodological heterogeneity limits the generalizability of results and may lead to misinterpretations in phase-based comparisons (Meignié et al., 2021). Furthermore, differences in sample characteristics and sport-specific training structures also contribute to the variability of outcomes. Physiological responses of elite endurance athletes cannot be evaluated in the same manner as those of female team sport athletes. Additionally, uncontrolled variables such as contraceptive use, training intensity, sleep, and nutrition make it difficult to directly observe hormonal effects. Therefore, understanding the relationship between the menstrual cycle and performance requires not only analyzing hormonal fluctuations but also holistically evaluating their interaction with training load, recovery capacity, and psychophysiological responses.

This study aims to systematically examine the growing body of literature in recent years and to reveal, in light of current evidence, the variations in training performance of female athletes across the phases of the menstrual cycle. By addressing methodological discrepancies and inconsistencies among findings in the literature, it seeks to develop a comprehensive understanding of how hormonal fluctuations influence athletic performance and to provide practice-oriented recommendations based on this integrative perspective.

## METHOD

### Research group (population-sample)

Since this study is a narrative literature review, no human participants were involved. Accordingly, ethical approval was not required. The review was conducted by examining peer-reviewed articles focusing on the effects of menstrual cycle phases on athletic performance in female athletes.

### Data collection tools

The data collection tools consisted of electronic databases and digital scientific repositories. The primary databases searched were PubMed, Scopus, Web of Science, Google Scholar, and ResearchGate. Search terms included *"menstrual cycle," "female athletes," "training performance," "hormonal fluctuation," "estrogen," "progesterone," "periodization,"* and *"recovery."* Boolean operators (AND, OR) were used to refine and combine keywords.

### Data collection/processing method

Articles published between 2015 and 2024 were systematically screened. Only peer-reviewed journal papers written in English were included. *Furthermore, one early online publication from 2025 was included to maintain the currency of the review.*

1. Studies examining menstrual cycle phase–based variations in performance or physiology,
2. Studies involving healthy, eumenorrheic female participants or athletes, and
3. Reviews or experimental studies addressing hormonal mechanisms, performance metrics, or applied training recommendations.

### Data analysis

A descriptive synthesis approach was adopted. Findings from the selected studies were compared in terms of performance domains (strength, endurance, coordination, recovery) and analyzed across menstrual cycle phases (menstrual, follicular, ovulatory, luteal). Methodological variables—such as phase verification methods, sample characteristics, contraceptive control, and sport type—were extracted and summarized in *Table 1*. The analysis emphasized the identification of common patterns, methodological inconsistencies, and applied recommendations rather than statistical aggregation, consistent with the narrative review framework.

## FINDINGS

### Physiology of the menstrual cycle and hormonal mechanisms

The menstrual cycle is one of the fundamental biological processes that regulates the physiological rhythm of female athletes. Lasting approximately 28 days, this cycle is controlled by the hypothalamic–pituitary–ovarian axis, whose hormonal feedback mechanisms trigger a series of physiological changes that can directly influence athletic performance. Throughout the cycle, fluctuations in estrogen and progesterone levels play a decisive role in various parameters—from muscle tissue energy utilization and body temperature to pain threshold and recovery processes (Oosthuyse et al., 2022).

In the early days of the follicular phase, estrogen levels are relatively low; during this period, menstrual bleeding continues, and the body primarily relies on carbohydrate-based energy metabolism. As the cycle progresses and estrogen levels rise, protein synthesis in muscle tissue is stimulated, neuromuscular efficiency increases, and there is a shift toward greater lipid oxidation for energy utilization (Kissow et al., 2022). This process also helps preserve intramuscular glycogen stores and supports a more sustainable balance in energy production. Elevated estrogen levels improve blood flow within muscle tissue, facilitating oxygen transport and accelerating post-exercise microtissue repair. Consequently, performance during strength and power training may be expressed more efficiently (McNulty et al., 2020). Moreover, the increase in estrogen contributes to protecting the muscle membrane from damage, thereby enhancing recovery potential.

During the ovulatory phase, estrogen reaches its peak level, followed shortly by a rise in progesterone. This transitional period represents a critical stage for thermoregulation; body temperature slightly increases, fluid and electrolyte balance shifts, and heat tolerance may decrease. As a result, performance reductions can be observed during high-intensity exercise in hot environments (Bruinvels et al., 2022). Additionally, heart rate variability may decrease, and the cardiovascular load can increase, requiring careful attention to aerobic endurance capacity. However, the surge in neuromuscular activation associated with elevated estrogen contributes to improved reflex speed and muscle contraction efficiency. Consequently, this phase may provide an advantage in activities demanding short bursts of power and agility. Therefore, it can be regarded as a dual-faceted period for performance—one that carries both potential risks and opportunities.

With the transition to the luteal phase, progesterone becomes the dominant hormone, leading to notable shifts in metabolic processes. The body increasingly relies on fat oxidation for energy production; however, basal body temperature and heart rate also rise during this period. The elevated thermal load causes the cardiovascular system to expend more energy and increases oxygen consumption during exercise. This can result in an earlier onset of fatigue, particularly during prolonged endurance activities. As thermal stress intensifies, endurance performance may decline, hydration balance may be disrupted, and perceived exertion tends to increase (Taylor et al., 2024). Moreover, the sedative effect of progesterone on the central nervous system can slightly delay motivation and reaction times. Progesterone also contributes to ligament laxity, which may elevate the risk of injury in joints such as the knees and ankles (Antero et al., 2023). Therefore, managing training intensity, maintaining proper hydration strategies, and incorporating proprioceptive exercises during the luteal phase may help sustain performance continuity and reduce injury risk.

At the biological level, estrogen enhances mitochondrial function in muscle cells, increases oxidative capacity, and supports antioxidant defense, whereas progesterone can suppress some of these effects. The opposing actions of these two hormones form the fundamental mechanism underlying performance variations across the menstrual cycle. From a neuromuscular perspective, estrogen facilitates synaptic transmission, thereby improving reflex speed and muscle activation, while progesterone's inhibitory influence may slow motor responses (Oosthuyse et al., 2022). The physiology of the menstrual cycle determines performance fluctuations not merely through the absolute levels of hormones but through the dynamic interaction between them. Differences in performance observed between cycle phases stem from shifts in energy substrate utilization, variations in neuromuscular excitability, changes in pain threshold, and alterations in thermoregulation. Therefore, considering menstrual cycle phases in training design for female athletes should be viewed as an essential strategy for enhancing physiological adaptation and minimizing injury risk.

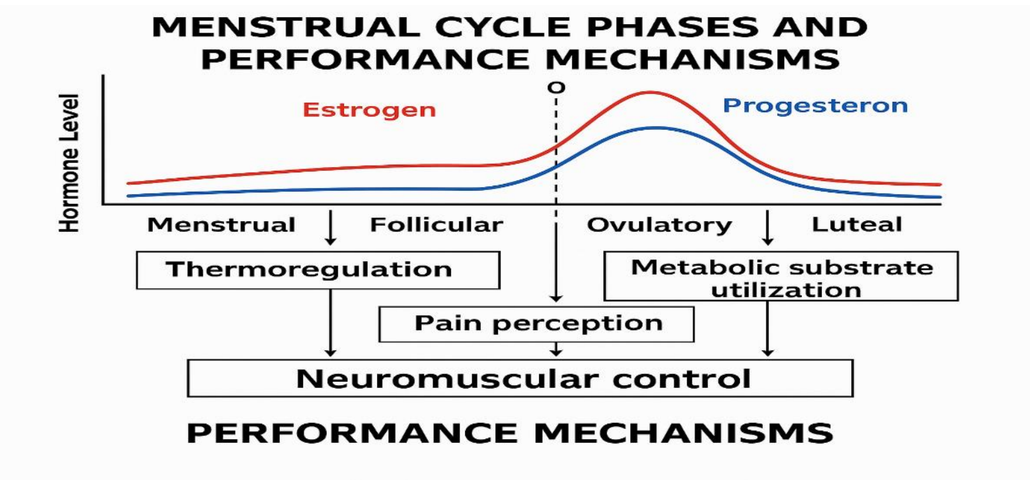


**Figure 1. Menstrual cycle phases and performance mechanisms in female athletes**

**Effects across performance domains**

Hormonal fluctuations observed throughout the menstrual cycle can influence female athletes' performance not only in terms of energy production or strength output but also with respect to neuromuscular coordination, recovery, and psychophysiological responses. However, these effects vary depending on the phase of the cycle, individual hormonal responsiveness, and training intensity (McNulty et al., 2020). The following sections outline the key aspects of these variations across different performance components.

The follicular phase of the menstrual cycle is characterized by a gradual increase in estrogen levels, which supports protein synthesis within muscle tissue and enhances mitochondrial energy production. Several studies have reported that strength training performed during this phase leads to more pronounced muscle hypertrophy and improved neuromuscular efficiency (Kissow et al., 2022). Electromyographic data indicate that motor unit activation is higher, muscle contraction velocity is increased, and fatigue threshold occurs later in the follicular phase (Moore et al., 2024). These outcomes can be attributed to estrogen's facilitative effect on synaptic transmission and its role in enhancing oxidative capacity. In contrast, as progesterone becomes dominant during the luteal phase, alterations in intracellular calcium regulation may disrupt the coordination of muscle activation. Consequently, high-intensity strength training conducted during the luteal phase may yield lower efficiency and performance outcomes (Antero et al., 2023).

Findings related to endurance performance present a more inconsistent picture. Due to estrogen's glycogen-sparing effect, studies have reported that during the follicular phase, energy efficiency improves, and oxidative metabolism operates more effectively in prolonged aerobic exercise (Oosthuyse et al., 2022). However, some controlled studies have found no significant differences in endurance performance across menstrual phases (Taylor et al., 2024). Such discrepancies may stem from variations in hormonal levels, environmental conditions, temperature, hydration status, and individual hormonal thresholds. During the luteal phase, increased body temperature and thermoregulatory strain may contribute to decreased performance in endurance activities performed in hot environments. Conversely, enhanced cardiovascular efficiency in the follicular phase can positively influence heart rate stability and oxygen utilization during prolonged exercise (Bruinvels et al., 2022). Therefore, phase-based variations in endurance performance should be understood as a multilayered process shaped by the interplay of biological, environmental, and psychological factors.

From the perspective of skill, coordination, and motor control, subtle yet distinct differences can be observed across the phases of the menstrual cycle. During the ovulatory phase, the stimulatory effects of estrogen on the central nervous system may enhance reflex speed and sensory perception. This can create a short-term performance advantage in sports where technical precision, balance, and reaction time play a critical role (Domínguez-Muñoz et al., 2024). Estrogen's facilitative effect on synaptic transmission improves the rate of muscle activation and motor unit synchronization, resulting in smoother motor control, particularly in coordination-dependent tasks. Athletes have been reported to exhibit higher accuracy scores in balance assessments and reaction time tests during this phase. In contrast, the elevated progesterone levels of the luteal phase exert an inhibitory influence on the central nervous system, which can slow motor conduction velocity and reduce proprioceptive sensitivity. This period may be characterized by delayed reflex responses, reduced movement accuracy, and minor disruptions in muscle contraction timing. Such neuromotor delays may lead to performance instability, especially during movements involving rapid direction changes or sudden stops. Studies have shown increased error rates and prolonged reflex response times in motor accuracy tests during this phase. Moreover, progesterone's relaxing effect on ligament tissue can negatively affect joint stability, increasing susceptibility to knee and ankle injuries (Antero et al., 2023). These findings indicate that the menstrual cycle represents a complex neurophysiological mechanism influencing not only energy metabolism but also neuromuscular communication. Therefore, when designing training programs according to menstrual phases, it is crucial to consider not only physiological parameters but also the phase-specific sensitivity of motor skill and coordination components to ensure performance consistency.

Recovery, sleep quality, and perceived exertion (RPE) levels are also closely associated with the menstrual cycle. The antioxidant and membrane-protective properties of estrogen contribute to accelerated post-exercise recovery during the follicular phase. In this phase, inflammatory responses within muscle tissue are reduced, muscle damage repair occurs more rapidly, and energy stores are replenished more efficiently. In contrast, the rise of progesterone during the luteal phase exerts a sedative effect on the central nervous system, which may reduce sleep depth and lead to decreased morning heart rate variability (HRV) values (Seddik et al., 2025). These physiological changes can increase fatigue perception and prolong the duration of muscle damage. Some studies have reported higher delayed-onset muscle soreness (DOMS) scores and elevated RPE values during the luteal phase (Solli et al., 2020). Therefore, reducing training load or prioritizing recovery-focused sessions during this period may be beneficial for maintaining performance continuity.

Overall, the effects of menstrual cycle phases on performance are not unidirectional. Even within the same phase, individual hormone levels, lifestyle factors, training history, and psychological state play a decisive role in determining performance outcomes. The primary reason for the inconsistencies observed in the literature lies in this individual and methodological variability. Therefore, when developing a phase-based training approach for female athletes, it is essential to consider not only the biological phase itself but also the athlete's unique physiological response profile.

**Summary of Phase-Specific Performance**

| Menstrual Cycle Phase | | Effects on Performance |
|---|---|---|
| Menstrual | | Low muscle performance<br>High perceived exertion<br>Reduced coordination |
| Follicular | | Increased muscle strength<br>Improved neuromuscular fficiency<br>Enhanced endurance |
| Ovulatory | | Peak power and strength<br>Potential performance benefits<br>Improved coordination |
| Luteal | | Decreased endurance<br>Higher body temperature<br>Greater fatigue |

**Figure 2. Summary of menstrual cycle phase-specific effects on athletic performance**

**Methodological differences and limitations in the literature**

Studies examining the effects of menstrual cycle phases on athletic performance are notable not only for the diversity of their findings but also for their methodological discrepancies. A substantial portion of the conflicting results in the literature arises from inconsistencies in phase verification techniques. In some studies, menstrual phases have been determined solely through the calendar method, relying on participants' self-reports. While this approach is practical, its reliability is limited due to the natural interindividual variability in hormonal fluctuations. In contrast, objective methods such as luteinizing hormone (LH) testing, basal body temperature (BBT) tracking, or serum hormone assays enhance phase accuracy but are more difficult to implement (Meignié et al., 2021). Particularly in field-based studies or those with large sample sizes, the use of such biochemical verification tools remains limited. This leads to ambiguity in phase classification and, consequently, significant constraints on the comparability of results (McNulty et al., 2020). These methodological challenges affect not only measurement reliability but also raise questions about how findings may vary according to participant characteristics. Indeed, participant profiles represent another crucial factor influencing the consistency of outcomes.

Participant profiles constitute another critical variable influencing the consistency of results. Some studies have included elite-level athletes, while others have examined recreational or amateur female participants. Elite athletes may possess a higher adaptive capacity to hormonal fluctuations due to their consistent training histories, whereas individuals with lower training experience tend to exhibit more pronounced performance variations (Antero et al., 2023). Consequently, even tests conducted within the same menstrual phase may yield differing outcomes depending on the participant group. Moreover, certain studies have focused exclusively on endurance athletes, while others have evaluated strength-based, aesthetic, or team sports collectively. This heterogeneity makes it difficult to clearly distinguish the sport-specific effects of menstrual phases (Meignié et al., 2021). Therefore, participant diversity not only limits the generalizability of findings but also directly affects methodological consistency in phase-based comparisons.

Another critical variable is the use of hormonal contraceptives. Combined oral contraceptives suppress estrogen and progesterone levels, thereby largely eliminating hormonal fluctuations. However, in some studies, participants using contraceptives were included in analyses without proper control or separation. This has led to the evaluation of naturally cycling women and contraceptive users within the same category, effectively masking the impact of hormonal differences (Antero et al., 2023). Moreover, athletes using contraceptives may exhibit distinct physiological responses in terms of muscle hypertrophy, recovery processes, or pain perception, further limiting the generalizability of findings (Oosthuyse et al., 2022). At this stage, it is also essential to consider not only hormonal factors but the influence of measurement conditions on outcomes. Indeed, the timing of performance assessments and environmental conditions represent additional determining factors that can significantly affect results.

Conducting exercise tests at different times of day can lead to deviations in parameters such as heart rate variability (HRV) and body temperature. When diurnal hormonal fluctuations are not accounted for particularly during the luteal phase, where thermoregulation plays a significant role endurance data may become misleading (Seddik et al., 2025). Similarly, studies that fail to control for environmental variables such as ambient temperature, humidity, and altitude tend to exhibit weaker internal validity when evaluating phase differences. Sample size and statistical power also represent key limitations within the literature. Most existing studies have been conducted with small samples ranging from 15 to 30 participants, making it difficult to detect statistically significant differences between menstrual phases (Taylor et al., 2024). Furthermore, the majority of research relies on single-session testing rather than longitudinal tracking, neglecting the dynamic nature of transitions between phases. This methodological gap hinders the ability to explain the relationship between menstrual cycle and performance from a temporal perspective.

Given these limitations, it is crucial that future research be conducted using more standardized protocols. Integrating multiple biochemical methods for phase verification, clearly reporting confounding variables such as contraceptive use, and analyzing different sport disciplines separately will help reduce inconsistencies within the literature. However, achieving this goal first requires adopting a holistic research approach that views the menstrual cycle not merely as a "variable," but as a fundamental biological component of individual performance.

**Table 1. Summary of participant characteristics and phase verification methods**

| Study | Participant Profile | Phase Verification Method | Hormonal Contraceptive Control | Sample Size | Sport Type | Methodological Notes |
|---|---|---|---|---|---|---|
| McNulty et al., 2020 | Mixed (recreational–elite) | Serum hormone + LH test | Reported, analyzed separately | n=78 | Multiple | Meta-analysis; limited phase standardization |
| Meignié et al., 2021 | Elite athletes | LH test + BBT | Controlled | n=55 | Endurance | Strict phase verification; small sample |
| Taylor et al., 2024 | Endurance-trained | Serum hormone | Controlled | n=42 | Endurance | High internal validity; no phase difference found |
| Antero et al., 2023 | Elite rowers | LH test | Reported | n=61 | Rowing | Real-world data; HC and non-HC compared |
| Kissow et al., 2022 | Trained females | Calendar + LH test | Excluded HC users | n=48 | Resistance | Strength-focused, phase-based RT |
| Seddik et al., 2025 | Elite volleyball | Calendar | Not reported | n=36 | Team sport | Time of day controlled; basic phase identification |
| Moore et al., 2024 | Elite team athletes | Self-reported + partial LH | Not reported | n=30 | Team sport | Applied setting; practical design |

**Practical implications: Recommendations for coaches and athletes**

Understanding the effects of menstrual cycle phases on athletic performance requires not only a physiological evaluation but also an individualized approach to training design. The hormonal rhythms of female athletes can influence energy metabolism, muscular endurance, motivation, and recovery processes in diverse ways. Therefore, planning training loads according to menstrual phases is crucial for maintaining performance continuity and minimizing injury risk (Moore et al., 2024).

The follicular phase is characterized by a gradual rise in estrogen levels and represents the period when muscle tissue is most responsive to protein synthesis. During this phase, strength-, speed-, and power-oriented training may offer higher adaptation potential (Kissow et al., 2022). The antioxidant properties of estrogen help reduce muscle damage and facilitate recovery. Coaches are therefore advised to progressively increase training loads during this period and closely monitor athletes' perceived exertion (RPE). Additionally, since energy metabolism functions more efficiently, nutrition plans that maintain a balanced use of carbohydrates and fats are recommended (Oosthuyse et al., 2022). These physiological advantages form the foundation for understanding performance fluctuations observed in subsequent phases and provide an essential reference point for planning the later stages of the cycle.

During the ovulatory phase, performance potential may temporarily peak. Increased neuromuscular activity, shortened reaction time, and heightened motivation make this phase suitable for technical training sessions or competition preparation. However, since elevated estrogen levels can increase ligament laxity, the risk of injury—particularly during rapid direction changes or jumping movements—should not be overlooked (Antero et al., 2023). Coaches are therefore encouraged to balance joint loading when planning high-intensity sessions and to incorporate protective strength exercises, especially targeting the knee and ankle regions.

The luteal phase is dominated by progesterone and is characterized by increases in basal body temperature and heart rate. During this phase, the body expends more energy, and the thermoregulatory load intensifies. Consequently, maintaining fluid electrolyte balance becomes critical, particularly during training in hot environments. It is recommended to increase hydration, slightly reduce training intensity, and schedule recovery-oriented sessions (Seddik et al., 2025). Since carbohydrate oxidation may decrease during the luteal phase, energy intake especially from complex carbohydrates should be adequately supported. Additionally, the sedative effects of progesterone on the nervous system should be considered, and appropriate sleep hygiene practices should be implemented to optimize recovery and overall well-being.

During the menstrual phase, symptoms such as pain, fatigue, and decreased motivation can affect athletes not only physically but also psychologically. In this phase, instead of high-intensity training, technical drills, low-intensity coordination exercises, or active recovery sessions may be more appropriate (Carmichael et al. (2021). Psychological support strategies (such as breath control, relaxation exercises, and mindfulness-based approaches) can help reduce pain perception and maintain mental focus. Coaches are encouraged to engage in empathetic communication, taking into account athletes' emotional and physical feedback, which can help alleviate performance pressure and foster a more supportive training environment (Majumder et al., 2022).

In team sports, the impact of menstrual cycle variations on coordination and tactical preparation is more complex. Team performance homogeneity can be influenced by individual physiological rhythms. Therefore, it may be beneficial for coaches to implement individualized training loads and, when necessary, apply rotation strategies according to the athletes' menstrual phases (Vogel et al., 2023). Furthermore, normalizing menstrual cycle tracking among female athletes and integrating this data into training management while maintaining privacy can support long-term performance consistency. Ultimately, a menstrual cycle–aware training approach not only optimizes performance but also enhances athletes' bodily awareness and self-management skills. The effectiveness of this approach is tied not only to physiological monitoring but also to factors such as communication, education, and psychological support. For coaches, the primary goal should be to recognize the distinct physiological conditions of each phase and adapt the training process without imposing additional pressure.

**Future research directions and gaps**

Although research examining the effects of menstrual cycle phases on female athletic performance has gained significant momentum over the past decade, methodological inconsistencies and measurement limitations have prevented the establishment of a comprehensive model. The most prominent gap in the literature lies in the lack of standardization of phase verification methods. Some studies rely on calendar-based approaches, while others utilize LH testing or serum hormone assays. This methodological diversity reduces the scientific consistency of phase definitions and limits the comparability of results (Meignié et al., 2021). To address this issue, future studies should incorporate multiple biochemical verification techniques and adopt an internationally standardized reporting framework for phase identification (McNulty et al., 2020).

Another critical research need concerns the limited number of sport-specific comparative analyses. Existing studies have largely focused on endurance and resistance-based sports, while data from aesthetic, combat, and team sports remain insufficient (Vogel et al., 2023). Given that each discipline differs in energy demands, neuromuscular load, and tactical requirements, the influence of menstrual phases is likely to vary accordingly. Therefore, sport-specific comparative research designs would not only enhance practical applicability but also help clarify the contextual nature of the hormone–performance relationship. In particular, multi-center studies involving elite female athletes could provide universally relevant reference data in this domain (Taylor et al., 2024). Most existing studies have been limited to cross-sectional designs; however, the menstrual cycle is inherently a recurring biological process, and longitudinal monitoring is indispensable for understanding its dynamic nature. Repeated measurements within the same individuals across multiple cycles can reveal the cumulative effects of interphase transitions on performance outcomes. Accordingly, future research should prioritize the development of personalized menstrual cycle modeling (Ekenros et al., 2024). Such models would enable the creation of multidimensional approaches that integrate not only hormonal levels but also individual recovery profiles, heart rate variability, sleep quality, and psychological state.

In recent years, advances in biotechnology and wearable sensor technologies have ushered in a new era in menstrual cycle monitoring. Sensors capable of tracking indicators such as skin temperature, heart rate, oxygen saturation, and HRV in real time are making it possible to extend laboratory-grade measurements into field settings. Integrating these systems with menstrual cycle tracking allows for real-time observation of how sudden hormonal fluctuations are reflected in performance parameters (Oosthuyse et al., 2022). Furthermore, the application of artificial intelligence–based algorithms to analyze such data could enable automated training and recovery planning tailored to individual cycle profiles (Kissow et al., 2024). This approach has the potential to establish the concept of *hormone-based personalized periodization* as a standard practice in future sport science. To clarify the relationship between the menstrual cycle and performance, future studies must adopt designs that are stronger both in biological precision and applied validity. Standardizing phase verification, expanding sport-specific and longitudinal research, integrating next-generation sensor data, and promoting algorithmic analytics will substantially narrow current knowledge gaps in this field. Integrating female physiology into the science of training will not only optimize athletic performance but also empower female athletes by reframing their biological cycles as sources of strength and performance potential.

## CONCLUSION

The menstrual cycle is increasingly regarded not merely as a biological variable influencing female athletes' performance but as a dynamic mechanism that shapes individual adaptation processes. Fluctuations in hormone levels do not yield identical outcomes for every athlete, since performance emerges as a composite of multiple factors such as genetic makeup, training history, nutritional status, psychological balance, and recovery capacity (McNulty et al., 2020). Therefore, the menstrual cycle should not be perceived as a limitation to performance, but rather as a natural process that can be managed through training programs aligned with the athlete’s biological rhythm. The inconsistencies observed in the literature primarily stem from methodological heterogeneity. Variations in phase verification techniques, ambiguities regarding contraceptive use, limited sample sizes, and inconsistencies in testing schedules have all directly influenced research outcomes (Meignié et al., 2021). These issues reflect the insufficient standardization of female physiology within the broader framework of training science. Future implementation of more consistent and multi-center research protocols will enable the reliable development of hormone-based training models (Taylor et al., 2024).

A training approach that is sensitive to hormonal cycles not only helps maintain female athletes’ performance but also serves as a tool to support their long-term development. When the unique biological conditions of each phase are taken into account, it becomes possible to individualize training loads, recovery periods, and nutritional strategies (Kissow et al., 2022). Such an approach lays the groundwork for establishing *hormone-based periodization* as a core principle in the future of sport science. Personalized training programs that integrate menstrual cycle phases represent a holistic framework capable of enhancing both the physiological and psychological resilience of female athletes. This perspective demonstrates that sex-based biological differences in sport should not be viewed as limitations, but rather as strategic components of performance optimization.

**Strengths and limitations of the study**

This study serves as a comprehensive review that examines the effects of menstrual cycle phases on training performance in female athletes through a multidimensional lens informed by recent literature. One of its key strengths lies in presenting an analytical framework that integrates various performance domains strength, endurance, coordination, and recovery with hormonal fluctuations. By addressing both the underlying biological mechanisms and offering practical recommendations for coaches and athletes, the study effectively bridges the gap between theoretical knowledge and applied practice. Furthermore, the inclusion of high-impact studies published within the past five years enhances the currency and reliability of the findings. In this respect, the review stands as an up-to-date reference source in the emerging field of menstrual cycle sensitive training design.

However, this study also has several limitations. First, the methodological diversity of the existing literature and inconsistencies in phase verification methods made direct data comparison challenging. Some studies relied on small sample sizes, while others used self-reported phase determination methods. Although these approaches allowed for identifying general trends, they limited the ability to draw precise quantitative conclusions. Additionally, most of the included studies were conducted in Europe, which may restrict the representativeness of female athletes from regions with different climates, cultures, and nutritional contexts. Another limitation was the inability to directly incorporate individual hormonal variations and psychological factors within the scope of this review, as such data were rarely reported consistently across studies. Therefore, while this review effectively highlights general trends in performance, it remains limited in explaining individual variability. Conversely, it establishes a systematic foundation for future research involving phase-verified, longitudinal, and sport-specific designs. Particularly, emerging approaches that integrate personalized cycle modeling, biosensor data, and hormonal profiling will serve to strengthen the conceptual framework presented in this review.

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| *Idea or Notion* | *Form the research hypothesis or idea* | Esin Çağla ÇAĞLAR |
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| *Literature Review* | *Review the literature required for the study* | Esin Çağla ÇAĞLAR |
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