



International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Operating Publisher
SciFormat Publishing Inc.
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,
Calgary, Alberta, T3E0A7,
Canada
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ARTICLE TITLE PHASE-SPECIFIC TRAINING IN EUMENORRHEIC WOMEN: THE
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PERFORMANCE AND ADAPTATION: A LITERATURE REVIEW

DOI [https://doi.org/10.31435/ijitss.2\(50\).2026.5248](https://doi.org/10.31435/ijitss.2(50).2026.5248)

RECEIVED 14 February 2026

ACCEPTED 30 April 2026

PUBLISHED 11 May 2026

LICENSE



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PHASE-SPECIFIC TRAINING IN EUMENORRHEIC WOMEN: THE ROLE OF MENSTRUAL CYCLE HORMONAL VARIABILITY IN PERFORMANCE AND ADAPTATION: A LITERATURE REVIEW

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ABSTRACT

Background: The menstrual cycle is a fundamental physiological rhythm in eumenorrheic women, driven by fluctuations in estrogen and progesterone. While these hormones influence substrate metabolism and thermoregulation, their actual impact on athletic performance remains debated.

Aim: This narrative review aims to evaluate the effects of menstrual cycle phases on acute exercise performance and chronic training adaptations, and to provide evidence-based practical recommendations.

Materials and Methods: A comprehensive literature search was conducted across PubMed, Google Scholar, and Scopus databases, covering original research and systematic reviews published between 2005 and 2025. Analysis focused on eumenorrheic athletes with a particular emphasis on studies utilizing biochemical phase verification.

Results: Aerobic capacity (VO₂max) and running economy remain stable across the cycle. While follicular-phase resistance training may offer superior strength gains in some cohorts, the broader evidence is inconsistent. A significant disconnect exists between physiological capacity and subjective perception, with athletes reporting performance decrements during the late luteal phase due to cycle-related symptoms.

Conclusions: Current evidence does not support the universal application of rigid, phase-based training models for eumenorrheic athletes. The high inter-individual variability in cycle characteristics and symptom severity suggests that a generalized approach is insufficient. Instead, practitioners are encouraged to adopt an individualized "symptom-based" monitoring strategy, adjusting training loads in response to specific athlete feedback rather than presumed physiological shifts.

KEYWORDS

Menstrual Cycle, Exercise Physiology, Strength Training, Female Athlete, Periodization

CITATION

Weronika Trynkiewicz, Monika Stępińska, Marta Omiecińska, Alicja Maciejewska, Maja Kaczor, Zuzanna Rybka, Julia Żak, Emilia Lenkiewicz, Karolina Dąbrowska, Jakub Winiarczyk. (2026) Phase-Specific Training in Eumenorrheic Women: The Role of Menstrual Cycle Hormonal Variability in Performance and Adaptation: A Literature Review. *International Journal of Innovative Technologies in Social Science*. 2(50). doi: 10.31435/ijitss.2(50).2026.5248

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1. Introduction: The menstrual cycle and athletic performance

1.1. Overview of hormonal physiology

The menstrual cycle is a complex physiological process regulated by the hypothalamic–pituitary–ovarian (HPO) axis, involving tightly coordinated fluctuations in gonadotropins and ovarian steroid hormones that orchestrate reproductive function and influence multiple systemic physiological processes (Thiyagarajan et al., 2024; Rosner et al., 2025). At the hypothalamic level, pulsatile secretion of gonadotropin-releasing hormone (GnRH) stimulates the anterior pituitary to release follicle-stimulating hormone (FSH) and luteinizing hormone (LH), which in turn regulate ovarian follicular development and steroidogenesis (Rosner et al., 2025). Estradiol and progesterone produced by the ovaries exert both negative and positive feedback on the hypothalamus and pituitary, enabling fine control of cycle progression (Thiyagarajan et al., 2024).

Physiologically, the cycle can be divided into four distinct phases – menstrual, follicular, ovulatory, and luteal – each characterized by specific hormonal patterns and functional changes in the ovary and endometrium (Munk et al., 2018).

The menstrual phase marks the onset of the cycle and occurs when circulating estradiol and progesterone concentrations decline sharply following regression of the corpus luteum from the previous cycle (Thiyagarajan et al., 2024). This hormonal withdrawal initiates endometrial shedding, while the reduction in steroid-mediated negative feedback permits a rise in FSH, enabling the recruitment of a new cohort of follicles (Rosner et al., 2025). Objective salivary hormone profiling demonstrates that both estradiol and progesterone reach their lowest concentrations during the early menstrual phase, supporting the physiological definition of this phase based on endocrine markers rather than calendar counting alone (Lafitte et al., 2024; Schmalenberger et al., 2021).

The follicular phase spans from menstruation to ovulation and is characterized by progressive follicular maturation driven by FSH stimulation. As follicles develop, granulosa cells increase estradiol synthesis, leading to a gradual rise in circulating estradiol concentrations across the mid- and late-follicular phases (Thiyagarajan et al., 2024). Estradiol plays a central role during this period by promoting endometrial proliferation and modulating central nervous system processes through estrogen-sensitive neural pathways (Rosner et al., 2025). Experimental studies further indicate that rising estradiol levels are associated with measurable changes in neural responsiveness, highlighting the broader psychophysiological relevance of follicular hormonal dynamics (Munk et al., 2018). High-resolution sampling studies reveal substantial inter-individual variability in both the timing and magnitude of estradiol elevation, underscoring the limitations of assuming uniform hormonal profiles across women (Lafitte et al., 2024; Schmalenberger et al., 2021).

Ovulation is initiated by a pronounced surge in LH, which occurs when sustained high estradiol concentrations switch from inhibitory to stimulatory feedback on the hypothalamic–pituitary axis (Thiyagarajan et al., 2024). This surge triggers the rupture of the dominant follicle and the release of the oocyte (Rosner et al., 2025). Neuroendocrine evidence suggests that rapid estradiol fluctuations around ovulation are accompanied by transient alterations in brain responsiveness to emotional stimuli, indicating that ovulatory hormonal dynamics may influence cognitive and affective processing in addition to reproductive events (Munk et al., 2018).

Following ovulation, the luteal phase is characterized by the formation of the corpus luteum and a marked increase in progesterone secretion, accompanied by moderate estradiol concentrations (Thiyagarajan et al., 2024). Progesterone supports endometrial differentiation while exerting systemic effects through progesterone-sensitive receptors (Rosner et al., 2025). Empirical hormone monitoring confirms that progesterone concentrations peak during the mid-luteal phase, although both absolute hormone levels and luteal phase duration vary considerably between individuals, reinforcing the importance of biochemical phase verification in physiological research (Lafitte et al., 2024; Schmalenberger et al., 2021).

Hormonal Effects on Metabolic and Physiological Systems

Fluctuations in ovarian steroid hormones exert systemic effects that extend well beyond reproductive tissues. Variations in estradiol and progesterone concentrations influence metabolic regulation, thermoregulatory control, cardiovascular function, and central nervous system activity, creating phase-specific physiological environments (Thiyagarajan et al., 2024; Speroff & Fritz, 2005).

Estradiol plays a pivotal role in modulating energy metabolism by influencing substrate selection. Higher estradiol availability has been associated with a metabolic profile favoring lipid utilization and sparing glycogen, effects that are particularly evident during the late follicular and mid-luteal phases (Draper et al., 2018). Conversely, progesterone, which predominates during the luteal phase, modifies these metabolic effects by influencing insulin sensitivity and resting energy expenditure. Endocrinological descriptions indicate that progesterone contributes to a distinct catabolic state during the luteal phase compared with the follicular phase (Rosner et al., 2025).

Progesterone also exerts a well-established thermogenic effect by acting on hypothalamic centers, leading to an elevation in basal body temperature (BBT) during the luteal phase (Speroff & Fritz, 2005). This temperature shift reflects coordinated central and peripheral mechanisms. Experimental studies confirm that resting and exercise-induced thermoregulatory responses differ between phases, with consistently higher core temperatures observed during progesterone-dominant states (Draper et al., 2018; Tagliapietra et al., 2024). These changes may influence tolerance to thermal stress during physical activity, potentially accelerating fatigue in hot conditions.

Furthermore, ovarian hormones influence cardiovascular regulation. Estradiol has been linked to vasodilatory effects mediated by endothelial pathways (Rosner et al., 2025), while progesterone may modulate plasma volume regulation and autonomic cardiovascular control. Controlled experimental work demonstrates that the menstrual cycle phase can alter cardiovascular and oxygen-transport responses during standardized submaximal exercise, particularly under hypoxic conditions (Tagliapietra et al., 2024).

Taken together, these cyclical variations create a dynamic physiological landscape. Understanding these phase-dependent effects provides the theoretical basis for investigating whether exercise performance and training adaptation fluctuate in sync with the menstrual cycle (Lafitte et al., 2024; Schmalenberger et al., 2021).

1.2. Methodological Challenges in Connecting Physiology to Performance

While the theoretical basis for phase-specific variations in exercise performance is physiologically sound, empirical findings in sports science remain inconsistent. Despite the distinct metabolic and neuromuscular environments created by estradiol and progesterone (Draper et al., 2018), systematic reviews frequently report trivial or insignificant differences in maximal physical performance across the menstrual cycle (McNulty et al., 2020). This discrepancy between physiological theory and performance outcomes is largely attributed to methodological limitations in existing research. A major concern is the lack of standardized phase verification – many studies rely solely on calendar counting, which fails to account for the substantial inter- and intra-individual variability in cycle length and hormonal timing identified in eumenorrheic women (Lafitte et al., 2024; Schmalenberger et al., 2021). Consequently, participants are often tested in hormonal states that do not align with the intended phase definitions (e.g., anovulatory cycles or shifted luteal phases), diluting potential effects. Therefore, understanding the impact of the menstrual cycle on training requires distinguishing between high-quality studies utilizing biochemical verification (urinary LH, serum/salivary hormones) and those relying on less precise methods (Schmalenberger et al., 2021).

2. Purpose of the review

With the increasing professionalization of women's sports, there is a growing interest in optimizing training strategies to account for female-specific physiology. While theoretical models suggest that the hormonal fluctuations characterizing the menstrual cycle could influence exercise metabolism and adaptation, empirical findings remain equivocal. Consequently, practitioners often face conflicting guidelines regarding the necessity of "phase-specific" training. The purpose of this review is to synthesize current evidence regarding the impact of the menstrual cycle on exercise physiology and performance in eumenorrheic women. Specifically, this paper aims to: (1) outline the physiological mechanisms by which ovarian hormones modulate metabolic and neuromuscular function; (2) evaluate the evidence for phase-based differences in aerobic, anaerobic, and strength performance; and (3) provide evidence-based practical recommendations for monitoring and programming, distinguishing between physiological capacity and symptom-based perception.

3. Materials and Methods

To ensure a comprehensive and objective synthesis of the current state of knowledge, a narrative literature search of PubMed, Google Scholar, and Scopus was performed. The search strategy focused on peer-reviewed original research, systematic reviews, and meta-analyses published between 2005 and 2025.

The primary search terms included combinations of: "menstrual cycle," "athletic performance," "strength training," "aerobic capacity," "female athlete," and "periodization." Studies were included if they involved eumenorrheic women and investigated the impact of hormonal fluctuations on at least one physical quality (strength, endurance, or power). Special consideration was given to "high-quality" studies that utilized biochemical verification (e.g., urinary LH surge testing or serum/salivary hormone profiling) rather than relying solely on the calendar method. Studies focusing on hormonal contraceptive users or clinical populations (e.g., PCOS) were excluded to maintain focus on the natural eumenorrheic cycle. A total of 20 key sources were selected for final analysis.

4. Results and Discussion

4.1. Aerobic capacity and running economy

From a physiological perspective, the theoretical framework suggesting that estrogen enhances lipid oxidation and glycogen sparing implies potential advantages for endurance performance during the follicular phase. However, empirical evidence largely indicates that aerobic capacity remains stable across the menstrual cycle in eumenorrheic women. No significant differences were found in running economy — defined as the oxygen cost of running at a submaximal velocity — and maximal oxygen uptake (VO_{2max}) between the follicular and luteal phases, suggesting that hormonal fluctuations do not substantially alter metabolic efficiency during steady-state exercise (Goldsmith & Glaister, 2020).

In addition to the absence of significant differences in VO_{2max} and running economy across menstrual cycle phases, several physiological mechanisms may explain why aerobic performance remains relatively stable despite hormonal fluctuations. Estradiol has been shown to enhance mitochondrial efficiency and promote greater reliance on lipid metabolism, which theoretically could support endurance performance by preserving glycogen stores (Draper et al., 2018). However, these metabolic shifts appear to occur within a

relatively narrow physiological range and are likely buffered by regulatory mechanisms that maintain homeostasis during exercise. As a result, substrate selection changes may occur without necessarily producing measurable differences in overall aerobic capacity. This concept is supported by metabolic profiling studies demonstrating rhythmic but moderate variations in energy substrate pathways across the menstrual cycle that do not necessarily translate into large-scale functional performance changes (Draper et al., 2018).

Another factor contributing to the stability of aerobic performance is the adaptability of cardiovascular and respiratory systems. Experimental investigations examining cardiorespiratory responses during submaximal exercise indicate that although certain physiological parameters—such as ventilation and heart rate responses—may vary slightly across cycle phases, oxygen delivery and utilization remain largely preserved (Tagliapietra et al., 2024). In practical terms, this means that the body compensates for hormonal fluctuations through integrated adjustments across multiple systems. For example, small alterations in plasma volume or thermoregulation may be offset by changes in peripheral circulation or ventilation patterns, thereby maintaining effective oxygen transport to working muscles.

Furthermore, large-scale analyses of menstrual cycle effects on exercise performance emphasize that the magnitude of hormonal influence on aerobic outcomes is generally small when compared to other determinants of endurance capacity. Factors such as training status, sleep quality, nutritional status, and environmental conditions often exert a substantially larger impact on endurance performance than endogenous hormonal fluctuations (McNulty et al., 2020). Consequently, even if minor physiological variations occur across the cycle, they may be masked by the inherent variability associated with exercise testing and day-to-day performance readiness.

Despite this stability in performance output, underlying physiological responses may vary. The luteal phase is characterized by a progesterone-mediated elevation in basal body temperature (approximately 0.3–0.5°C), which places an increased burden on thermoregulatory mechanisms (Giersch et al., 2020). Additionally, progesterone and aldosterone dynamics can influence plasma volume regulation. While it has been concluded that eumenorrheic women effectively maintain hydration status and fluid balance during exercise across all phases, the increased thermal strain in the luteal phase may elevate perceived exertion (RPE) and heart rate during prolonged exercise in hot environments, even if maximal capacity is preserved (Giersch et al., 2020).

The thermogenic effect of progesterone during the luteal phase is one of the most consistently documented physiological changes across the menstrual cycle. Progesterone acts on thermoregulatory centers within the hypothalamus, increasing the body's temperature set point and resulting in elevated resting core temperature and basal body temperature (Speroff & Fritz, 2005). During exercise, this elevated baseline temperature may reduce the available margin for heat storage before reaching critical thermal limits. Experimental research examining exercise responses under environmental stress has demonstrated that women exercising in the luteal phase may begin activity with a higher initial core temperature, potentially accelerating the onset of thermal strain during prolonged exertion (Giersch et al., 2020).

Despite these thermoregulatory differences, the impact on performance outcomes appears to be limited under temperate conditions. Well-trained individuals typically compensate through behavioral and physiological strategies, including increased sweating rate, peripheral vasodilation, and fluid intake adjustments. As a result, although thermoregulatory load may be slightly elevated during progesterone-dominant phases, the body is generally capable of maintaining stable aerobic performance when adequate hydration and environmental conditions are maintained (Giersch et al., 2020). This highlights the importance of distinguishing between physiological strain and actual performance limitation when interpreting menstrual cycle effects on endurance exercise.

Anaerobic power and team sport demands

In the context of anaerobic power and intermittent team sports, the influence of the menstrual cycle appears to be negligible for performance outcomes. A comprehensive analysis was conducted on female soccer players to assess whether cycle phase impacted physical performance metrics relevant to match play, utilizing a battery of tests including the Yo-Yo Intermittent Endurance Test Level 1, countermovement jumps (CMJ), and repeated sprint protocols (Julian et al., 2017). The results demonstrated that menstrual cycle phase had no significant effect on maximal strength, jumping ability, or high-intensity endurance running.

These findings suggest that in complex sporting environments, where performance is multifactorial, the biological noise introduced by hormonal fluctuations is likely overshadowed by other variables such as neuromuscular readiness, motivation, and tactical context. Consequently, current evidence supports the view that competitive athletes can maintain high-intensity work rates and explosive power output regardless of their hormonal status (Julian et al., 2017).

4.2. Strength and hypertrophy adaptations

In contrast to aerobic and anaerobic performance, the literature regarding resistance training adaptation presents more divergent findings, leading to significant debate regarding periodization strategies. The hypothesis that the follicular phase represents a "window of opportunity" for strength gains is based on the potential anabolic and neuro-excitatory effects of estradiol, contrasted with the potentially catabolic or inhibitory effects of progesterone.

The theoretical rationale for follicular-phase training advantages is rooted in the interaction between estradiol and skeletal muscle physiology. Estradiol has been implicated in several processes relevant to muscle adaptation, including satellite cell activation, modulation of muscle protein turnover, and enhanced neuromuscular signaling. These mechanisms suggest that periods characterized by higher estradiol concentrations may create a slightly more favorable anabolic environment for strength development. Additionally, estradiol may influence connective tissue properties and muscle stiffness, potentially improving force transmission during resistance exercise. Although these effects are supported by mechanistic and endocrinological research, their practical magnitude in trained populations remains difficult to quantify (Draper et al., 2018; Thiyagarajan et al., 2024).

Progesterone, which dominates during the luteal phase, may theoretically counteract some of these effects through its influence on protein metabolism and thermoregulation. Some endocrinological descriptions suggest that progesterone can increase resting energy expenditure and promote a metabolic environment that is less conducive to muscle protein accretion compared with estradiol-dominant phases (Rosner et al., 2025). However, the degree to which these hormonal influences translate into measurable differences in long-term strength development remains uncertain. Most resistance training adaptations are primarily driven by progressive overload, neuromuscular recruitment patterns, and training volume rather than short-term hormonal fluctuations within the physiological range observed in eumenorrheic women.

Experimental protocols capitalizing on this theory have yielded promising results. A high-frequency leg resistance training program concentrated in the follicular phase was shown to result in superior gains in maximal strength (1RM) and muscle power compared to a luteal-phase-concentrated protocol, despite identical total training volumes (Wikström-Frisén et al., 2017). Similarly, significantly greater increases in maximal isometric strength and muscle diameter following follicular-based training have been reported compared to luteal-based training (Sung et al., 2014). These studies suggest that concentrating training volume when estradiol levels are high and progesterone is low may optimize hypertrophic and neural adaptations.

Recent original studies examining strength and muscular performance across the menstrual cycle highlight a nuanced picture. A randomized crossover trial in women of varying training levels found that back squat performance and jumping ability did not differ significantly across cycle phases, although minor differences were observed depending on individual performance level and psychological state (Isenmann et al., 2024). In a case-control study of athletic and non-athletic girls, hand grip strength showed some phase-related variability, with higher values in certain follicular-phase measurements; however, the effects were inconsistent and influenced by training status (Soliman et al., 2024). Similarly, an investigation in trained women assessing muscular peak torque and perceptual responses revealed no consistent phase-dependent differences in maximal strength outcomes, though subjective recovery and fatigue varied between menstrual and non-menstrual phases (Vieira Sousa et al., 2024). Collectively, these findings suggest that menstrual cycle phase alone is unlikely to be a dominant determinant of maximal strength performance, and any training periodization solely based on phase should be approached cautiously.

One possible explanation for the divergent findings across resistance training studies relates to differences in participant characteristics and training protocols. Studies reporting larger phase-specific adaptations often involve relatively small cohorts or previously untrained participants, populations that may demonstrate more rapid neuromuscular improvements during early training phases (Sung et al., 2014). In contrast, investigations involving trained individuals frequently report smaller or negligible differences between phases, suggesting that training status may moderate the influence of hormonal fluctuations on strength development (Isenmann et al., 2024; Vieira Sousa et al., 2024).

Another methodological factor concerns the duration of training interventions. Strength adaptations typically occur over weeks to months, whereas hormonal fluctuations occur over a much shorter time scale. As a result, adaptations observed during a training study may reflect cumulative training exposure rather than the specific hormonal environment present during individual sessions. Consequently, attributing long-term strength gains solely to menstrual cycle phase may oversimplify the complex interaction between training stimulus, recovery processes, and endocrine regulation.

However, recent critical reviews advise caution in interpreting these results as a universal mandate for "menstrual cycle-based training" (Colenso-Semple et al., 2023). While some individual studies show large effect sizes, the broader body of literature is inconsistent, often plagued by methodological limitations such as small sample sizes and imprecise phase verification. It is argued that for the vast majority of athletes, consistent progressive overload remains the primary driver of adaptation, and the magnitude of hormonal influence may not be sufficient to warrant the logistical complexity of phase-based programming unless the athlete is at an elite level where marginal gains are decisive (Colenso-Semple et al., 2023).

4.3 Perceptual responses and symptomatology

While physiological measures of performance ($\dot{V}O_{2max}$, 1RM, sprint time) may show statistical stability across the cycle, the subjective experience of the athlete often tells a different story. Research highlights a critical disconnect between "measured" and "perceived" performance, where a significant proportion of elite female athletes reported perceiving their performance to be negatively affected during the late luteal and early menstrual phases, primarily due to symptoms such as dysmenorrhea (cramps), fatigue, and mood disturbances (Brown et al., 2021).

These symptoms can act as a barrier to training quality and motivation, even if physiological capacity is theoretically uncompromised. For instance, an athlete might be physically capable of hitting a specific split time, but the associated pain or discomfort may increase the perceived effort required to do so. This distinction is crucial for practitioners: the absence of physiological performance decrement does not invalidate the athlete's lived experience of difficulty. Therefore, managing the menstrual cycle in sport requires addressing not just the biological potential for force production, but also the management of symptoms that influence training availability and quality (Brown et al., 2021). A summary of the divergent findings regarding physiological versus perceptual responses across different physical qualities is presented in Table 1.

Table 1. Overview of selected studies investigating the effects of menstrual cycle phase on physical performance and training adaptation.

| Study | Population | Focus Area | Key Findings |
|-------------------------------|----------------------------------|--------------------------------------|--|
| Wikström-Frisén et al. (2017) | Resistance-trained women | Strength & Hypertrophy (Adaptation) | High-frequency training concentrated in the follicular phase resulted in superior gains in maximal strength (1RM) and power compared to luteal-phase training. |
| Sung et al. (2014) | Untrained young women | Strength (Adaptation) | Follicular phase-based training led to significantly greater increases in maximal isometric strength and muscle diameter compared to luteal phase-based training. |
| Julian et al. (2017) | Female soccer players | Anaerobic Power & Team Sport (Acute) | No significant differences were observed in countermovement jump, sprint performance, or intermittent endurance capacity across menstrual cycle phases. |
| Goldsmith & Glaister (2020) | Trained runners | Aerobic Endurance (Acute) | Running economy and $\dot{V}O_{2max}$ remained stable across the cycle. No significant physiological decrements were observed in the luteal phase despite temperature elevation. |
| Brown et al. (2021) | Elite athletes | Perception & Symptoms (Qualitative) | Athletes perceived their performance to be worse in the late luteal/early menstrual phase due to pain, fatigue, and mood disturbances, despite physiological stability. |
| Isenmann et al. (2024) | Women of varying training levels | Strength & Hypertrophy (Adaptation) | Back squat and jump performance did not differ significantly across cycle phases; minor differences were observed depending on performance level and psychological state. |
| Soliman et al. (2024) | Athletic and non-athletic girls | Hand Grip Strength (Adaptation) | Phase-related variability observed, with higher values in certain follicular-phase measurements; effects were inconsistent and influenced by training status. |
| Vieira Sousa et al. (2024) | Resistance-trained women | Muscular Peak Torque & Perception | No consistent phase-dependent differences were observed in maximal strength outcomes; subjective recovery and fatigue varied between menstrual and non-menstrual phases. |

Psychophysiological mechanisms may help explain why perceived performance fluctuates more noticeably than objective performance metrics. Hormonal changes across the menstrual cycle are known to influence neurotransmitter systems involved in mood regulation, including serotonergic and dopaminergic pathways. Fluctuations in estradiol and progesterone can therefore affect emotional processing, fatigue perception, and motivation levels, which may indirectly influence training experiences (Munk et al., 2018). These neuroendocrine effects may contribute to the subjective perception of reduced readiness or increased effort during certain phases of the cycle, even when physiological capacity remains unchanged.

Additionally, menstrual symptoms such as dysmenorrhea and premenstrual discomfort may alter movement patterns, sleep quality, and overall recovery status. Even relatively mild symptoms can accumulate to influence training quality over several days, particularly in high-performance environments where athletes operate close to their physiological limits. As a result, practitioners must consider both physiological capacity and symptom burden when evaluating training readiness across the menstrual cycle (Brown et al., 2021). This dual perspective helps reconcile the apparent discrepancy between stable laboratory performance measures and the fluctuating experiences reported by many athletes.

5. Practical applications & conclusion

5.1 Individual variability and the limitations of group means

The juxtaposition of physiological mechanisms with empirical performance data reveals a complex landscape. While ovarian hormones indisputably influence metabolic, thermoregulatory, and neuromuscular systems, these physiological shifts do not consistently translate into significant performance decrements at the group level. A critical systematic review of elite athletes suggests that the lack of consensus in the literature may stem from high inter-individual variability (Meignié et al., 2021). While "average" performance remains stable across the cycle, individual responses can vary dramatically; some athletes exhibit peak performance during the ovulatory phase, while others experience significant declines during the late luteal or early menstrual phases due to premenstrual symptoms (PMS) rather than physiological incapacity.

An additional factor contributing to the difficulty of establishing universal training recommendations is the inherent biological variability of the menstrual cycle itself. Even among eumenorrheic women, substantial variability exists in cycle length, hormone concentrations, and the timing of ovulation. High-resolution hormone monitoring studies demonstrate that estradiol and progesterone profiles can differ considerably between individuals, even when overall cycle length appears similar (Lafitte et al., 2024). Consequently, two athletes who both report a "28-day cycle" may experience markedly different hormonal environments on the same calendar day. This variability complicates the interpretation of research findings and highlights why standardized calendar-based training prescriptions may fail to capture the true physiological context of individual athletes.

Moreover, methodological analyses emphasize that relying solely on self-reported cycle tracking or calendar counting introduces significant misclassification risk in research studies (Schmalenberger et al., 2021). Without biochemical verification of ovulation, participants may be incorrectly categorized into follicular or luteal phases, which can dilute potential performance effects when data are averaged across groups. This methodological issue likely contributes to the inconsistent findings observed across the literature. As a result, practitioners should interpret group-based research cautiously and recognize that population averages may obscure meaningful individual responses to hormonal fluctuations.

Therefore, the application of a rigid, "one-size-fits-all" periodization model (e.g., universally programming high-intensity loads in the follicular phase) is not supported by current evidence. Generalized approaches fail to account for the heterogeneity of cycle characteristics, including cycle length, hormonal magnitude, and symptom severity (Meignié et al., 2021). Consequently, the focus of practitioners should shift from generic "phase-based training" to an "individualized monitoring approach," where the menstrual cycle is treated as a vital sign specific to each athlete.

5.2 Practical recommendations: A Symptom-Based Approach

For coaches and athletes, the primary goal should be to establish a longitudinal profile of the athlete's cycle and its associated symptoms. Rather than preemptively reducing training intensity based on textbook physiology, practitioners should implement a "symptom-based" modification strategy.

1. **Monitoring and Tracking:** Athletes should be encouraged to track their cycle start dates, duration, and daily symptoms (e.g., pain, fatigue, mood) alongside training metrics (RPE, load) for at least three to six months. This data allows for the identification of recurring patterns. If an athlete consistently reports high fatigue or lower back pain on days 26–28 of her cycle, training loads can be micro-adjusted proactively for those specific days, rather than altering the entire mesocycle (Meignié et al., 2021).

2. **Communication and Education:** Creating an environment where the menstrual cycle can be discussed openly is essential. The perception of performance is often more impacted than physiological capacity itself. Coaching interventions should focus on mitigating symptoms (e.g., adjusting warm-up protocols, hydration strategies in the luteal phase) rather than assuming performance incompetence (Brown et al., 2021).

3. **Strength Training Considerations:** For athletes specifically focused on hypertrophy or maximal strength development, there is a theoretical and partial empirical basis for front-loading volume in the follicular phase (Wikström-Frisén et al., 2017). However, this should only be implemented if the athlete is eumenorrheic, has a predictable cycle, and can tolerate the logistical complexity of such programming without compromising recovery.

In addition to symptom monitoring, integrating menstrual cycle awareness into broader athlete monitoring systems may enhance training decision-making. Modern performance environments increasingly rely on multi-factor monitoring approaches that combine subjective questionnaires, physiological markers, and workload metrics to evaluate athlete readiness. Within this framework, menstrual cycle tracking can serve as an additional contextual variable rather than a primary determinant of training prescription. For example, variations in sleep quality, perceived fatigue, or recovery scores reported during specific phases may help practitioners interpret fluctuations in performance metrics more accurately.

Education also plays a crucial role in effective menstrual cycle management within sport. Athletes who possess a basic understanding of hormonal physiology may be better equipped to interpret their own physical and psychological responses throughout the cycle. Open communication between athletes, coaches, and medical staff can reduce stigma and encourage early reporting of symptoms that may influence training availability. Qualitative research involving elite athletes indicates that many female competitors value environments in which menstrual health is openly acknowledged as part of overall athlete wellbeing and performance management (Brown et al., 2021).

Finally, practitioners should consider environmental and contextual factors when interpreting cycle-related responses. For instance, thermoregulatory strain associated with progesterone-mediated temperature elevation may become more relevant in hot environments or during prolonged endurance events (Giersch et al., 2020). In such cases, individualized hydration strategies, cooling interventions, and pacing adjustments may help mitigate potential discomfort without requiring substantial alterations to the overall training program.

5.3. Directions for future research

To resolve the remaining ambiguities in this field, future research must adopt more rigorous methodological standards. A major limitation of current studies is the reliance on calendar counting for phase verification. As noted in methodological guidelines, accurate research requires biochemical verification (urinary LH tests, salivary hormone profiling) to confirm ovulation and precise phase timing (Schmalenberger et al., 2021). Furthermore, there is a need for more longitudinal studies on elite populations, as training status may influence the body's sensitivity to hormonal fluctuations. Research should also distinguish between the physiological effects of hormones and the psychophysiological impact of menstrual symptoms, as these require different management strategies.

6. Conclusions

The menstrual cycle is a rhythmic physiological process that induces systemic changes in metabolism, thermoregulation, and neural function. However, the human body possesses robust homeostatic mechanisms that largely buffer these changes, allowing eumenorrheic women to maintain exercise performance across all cycle phases. Current evidence does not support the necessity of menstrual cycle-based training periodization for the general athletic population. Instead, the "best practice" involves a personalized approach: monitoring individual responses, managing cycle-related symptoms, and adjusting training loads only when specific patterns of fatigue or performance decline are identified. By moving away from generic prescriptions and towards individual responsiveness, coaches can better support the long-term health and performance of female athletes.

Importantly, the growing interest in menstrual cycle-informed training reflects a broader shift toward more inclusive and individualized approaches in sports science. Historically, much of exercise physiology research was conducted predominantly in male populations, which limited the understanding of female-specific physiological processes in athletic contexts. Expanding research in this field not only improves knowledge regarding hormonal influences on performance but also contributes to more equitable evidence-based practices in athlete preparation and health management.

However, the current body of evidence suggests that menstrual cycle effects on physical performance should be interpreted within a broader biopsychosocial framework. Hormonal fluctuations interact with numerous external factors, including training load, recovery status, psychological stress, and environmental conditions. Consequently, performance outcomes cannot be attributed solely to endocrine changes occurring within the menstrual cycle. Recognizing this complexity is essential for avoiding overly simplistic training models that attribute performance variability exclusively to hormonal phases.

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Data Availability Statement: The authors confirm that the data supporting this study are available in the article's references.

Conflict of Interest: Authors declare no conflict of interest.

In preparing this work, the authors used ChatGPT for the purpose of improving language and readability, text formatting, and verification of bibliographic styles. After using this tool/service, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

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