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ORIGINAL ARTICLE

Hormonal Cyclicity and Physical Performance - Review of the Literature

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ABSTRAKT

Introduction: The menstrual cycle involves a complex interaction of hormonal fluctuations that can influence various aspects of female athletic performance. Understanding these relationships has become increasingly important for optimizing training programs and supporting female athletes across different competitive levels.

Objective: This review synthesizes current evidence on how menstrual cycle phases and hormonal contraception affect physical performance in female athletes.

Material and methods: We conducted a comprehensive literature search across major databases including PubMed, Web of Science, and SPORTDiscus, focusing on studies published between 2020 and 2025 that examined menstrual cycle effects on athletic performance.

Conclusions: Current evidence suggests that menstrual cycle phase effects on performance are generally small and highly individualized. While some athletes do experience performance decrements during specific phases particularly the early follicular and late luteal phases, group-level effects are often minimal or inconsistent. Interestingly, perceptual symptoms and psychological well-being appear to influence performance more consistently than hormonal fluctuations alone. Hormonal contraception shows variable effects depending on type and formulation. Rather than applying universal cycle-based training modifications, we recommend individual monitoring and personalized approaches.

KEYWORDS

menstrual cycle, athletic performance, hormonal contraception, female athletes, endurance, exercise physiology

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1. Introduction

Women's participation in competitive sports has grown dramatically over recent decades, yet our understanding of female-specific physiological factors affecting athletic performance remains surprisingly incomplete. The menstrual cycle, with its cyclical fluctuations in reproductive hormones, represents a fundamental aspect of female physiology that has only recently garnered serious attention in sports science research. Understanding how these hormonal changes influence physical performance is essential for developing evidence-based training strategies that truly support female athletes.

Despite growing interest in this area, the relationship between menstrual cycle phases and athletic performance remains contentious. Some studies have reported significant performance variations across the cycle, while others have found minimal or no effects. This inconsistency has led to considerable debate among researchers, coaches, and athletes themselves about whether cycle-based training modifications are warranted or even beneficial.

The situation becomes even more complex when we consider hormonal contraception. A substantial proportion of female athletes use hormonal contraceptives, which fundamentally alter the natural hormonal milieu. These interventions can affect not only reproductive function but potentially also metabolic processes, muscle function, and recovery, which are crucial for athletic performance. Yet the evidence on how different contraceptive formulations impact performance outcomes remains fragmented and sometimes contradictory.

Adding another layer of complexity, recent research has highlighted that perceptual symptoms and psychological factors may play a more significant role than previously recognized. Athletes' subjective experiences of their menstrual cycle - including fatigue, mood changes, and perceived exertion - often correlate more strongly with performance outcomes than objective hormonal measurements. This raises important questions about the mechanisms underlying cycle-related performance changes and suggests that a purely physiological approach may be insufficient.

This review aims to synthesize the current evidence on menstrual cycle effects on athletic performance, with particular attention to recent studies published between 2020 and 2025. This review examines both strength/power and endurance performance outcomes, explores the impact of hormonal contraception, and consider the role of perceptual and psychological factors. Importantly, this review also addresses the methodological challenges that have complicated research in this area and discuss the substantial individual variability that characterizes hormonal responses and performance outcomes.

By critically evaluating the existing evidence, this review aims to provide practical guidance for athletes, coaches, and sports medicine professionals while identifying key areas where further research is needed. The aim is to move beyond simplistic generalizations toward a more nuanced, individualized understanding of menstrual cycle considerations in athletic training and competition.

2. Menstrual Cycle Physiology and Hormonal Fluctuations

To understand how the menstrual cycle may influence athletic performance, it is first necessary to consider the underlying hormonal dynamics. A typical menstrual cycle lasts approximately 28 days, although cycle length commonly ranges from 21 to 35 days. The cycle is traditionally divided into distinct phases, each characterized by different hormonal profiles that regulate reproductive function.

Menstruation marks the beginning of the follicular phase. During this early follicular phase, circulating estrogen and progesterone concentrations are at their lowest. As the follicular phase progresses, estrogen levels gradually increase and peak shortly before ovulation. This estrogen surge triggers the release of luteinizing hormone (LH), leading to ovulation, which typically occurs around day 14 in a typical 28-day cycle [1].

Following ovulation, the cycle enters the luteal phase, which is characterized by elevated progesterone levels alongside moderately high estrogen. The corpus luteum - the remnant of the ovulated follicle - produces these hormones to prepare the uterine lining for potential implantation. If pregnancy doesn't occur, the corpus luteum degenerates, causing both progesterone and estrogen levels to drop sharply. This hormonal withdrawal triggers menstruation, and the cycle begins anew [1].

Although this framework provides a useful reference, menstrual cycles vary considerably between individuals and even between cycles within the same individual. Variations in cycle length, ovulation timing and hormonal profiles pose substantial challenges for research seeking to associate specific cycle phases with performance outcomes.

Importantly, estrogen and progesterone exert systemic effects that extend beyond reproductive function.

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Estrogen influences glucose and lipid metabolism, protein synthesis, inflammation and thermoregulation - mechanisms that may be particularly relevant for endurance performance. Progesterone, in contrast, has thermogenic properties, affects respiratory drive, and may alter substrate utilization during exercise [2].

Emerging evidence also suggests that estrogen may exert protective effects on skeletal muscle, potentially reducing exercise-induced muscle damage and inflammation. This has led to the hypothesis that phases characterized by higher estrogen concentrations - such as the late follicular or mid-luteal phase - could be more favorable for high-intensity training or competition. However, as discussed in later sections, empirical evidence supporting this hypothesis remains inconsistent [3].

Hormonal fluctuations occur within the broader context of the hypothalamic-pituitary-ovarian (HPO) axis, which is sensitive to external stressors such as energy availability, psychological stress and training load. In some athletes, high training demands may disrupt normal menstrual function, resulting in cycle irregularity or even amenorrhea. This bidirectional relationship between athletic training and menstrual function further complicates interpretation of cycle--related performance effects [4].

Hormonal contraception introduces an additional layer of complexity. Combined oral contraceptives (COCs) suppress endogenous hormonal fluctuations, leading to relatively stable exogenous hormone levels during the active pill phase, followed by a withdrawal bleed during the placebo interval. Progestin-only contraceptives produce distinct hormonal profiles that may partially suppress ovulation while allowing limited hormonal variability [5].

Understanding these physiological foundations is essential for interpreting the performance-related research. Nevertheless, hormonal concentrations alone do not fully explain observed performance outcomes. Individual sensitivity to hormonal changes, training status, nutritional status, psychological variables and the sport-specific demands all contribute to the relationship between menstrual cycle physiology and athletic performance.

3. Effects of Menstrual Cycle Phases on Strength and Power Performance

From the theoretical perspective, fluctuations in estrogen and progesterone could influence neuromuscular function and consequently, strength and power performance. However, empirical findings present an inconsistent picture.

A comprehensive systematic review and meta-analysis by McNulty et al. [1] examined strength performance across menstrual cycle phases and demonstrated that, although some individual studies reported statistically significant differences, overall group-level effects were small and frequently non-significant. These findings suggest that cycle-related strength changes in strength performance are generally subtle rather than pronounced.

Where phase-related differences have been observed, results do not consistently align with theoretical predictions. Some studies report marginally higher strength during the follicular phase, potentially reflecting estrogen's anabolic and neuromuscular effects. In contrast, other investigations report no meaningful differences or even slightly enhanced performance during the luteal phase [1]. The inconsistency underscores the limited predictive value of cycle phase alone.

A recurring theme across literature is substantial inter-individual variability. Arantes et al. [13] for example, reported marked individual fluctuations in strength levels across the menstrual cycle, while group-level differences remained minimal. Similar patterns were observed by Cabre et al. [14], who found no cycle phase associated with universally superior strength or power performance in either naturally cycling women or hormonal contraceptive users.

Differences between maximal strength and explosive power outcomes have also been explored. It has been hypothesized that power-based tasks, which rely on rapid neuromuscular activation, which may be more sensitive to hormonal influences than maximal force production. Nevertheless, evidence supporting this distinction remains limited. Smith et al. [23] reported minimal and inconsistent effects of menstrual status on lower-body plyometric performance in female rugby league athletes, despite the explosive nature of the task.

Methodological limitations likely contribute to these heterogeneous findings. Many studies rely on calendar-based phase identification or indirect markers of ovulation, which may not accurately reflect individual hormonal profiles. Investigations using direct hormonal verification sometimes yield different results, highlighting the importance of methodological rigor [7].

Training status may further modulate responses. While it has been proposed that highly trained athletes might exhibit altered sensitivity to hormonal fluctuations, available evidence does not support

a consistent interaction between training level and cycle-related strength changes [8].

Overall, current evidence indicates that menstrual cycle phase is unlikely to be a primary determinant of strength and power performance for most athletes. However, meaningful cycle-related fluctuations may occur in certain individuals. Consequently, individualized monitoring rather than universal cycle-based training prescriptions appears to be the most appropriate approach.

4. Effects of Menstrual Cycle Phases on Endurance Performance

Endurance performance has been extensively studied in relation to menstrual cycle phase, largely because hormones may plausibly influence key physiological determinants of aerobic capacity. Estrogen and progesterone affect substrate metabolism, thermoregulation, cardiovascular and respiratory function, all of which are central to endurance activities. Nevertheless, empirical findings have proven more complex than early theoretical models suggested.

Several recent investigations have reported minimal or inconsistent effects of menstrual cycle phase on endurance performance. Oxfeldt et al. [16] examined endurance-trained women using rigorous phase verification methods and observed no consistent differences in performance across menstrual or oral contraceptive phases. These findings are notable given the high training status of participants and methodological rigor employed.

Some studies have reported small decrements in endurance performance during the early follicular or late luteal phases potentially related to altered thermoregulation, plasma volume changes, increased perceived exertion, or metabolic shifts in substrate utilization [9]. Yet the magnitude of these effects, when detected, tends to be small - often within the normal day-to-day variability in performance.

An interesting dimension of this research involves examining specific physiological responses during endurance exercise rather than just performance outcomes. Olenick et al. [21] studied cardiorespiratory responses to high-intensity interval exercise across the menstrual cycle and with oral contraceptive use. They found that while some physiological parameters (like heart rate and ventilation) showed minor variations across phases, these changes didn't translate into meaningful performance differences. This disconnect between physiological measurements and actual performance is a recurring puzzle in this field.

Thermoregulation has received particular attention, as progesterone's thermogenic effects elevate core body temperature during the luteal phase. Hayashi et al. [20] demonstrated phase-related differences in respiratory and thermoregulatory responses under heat stress. Importantly, these physiological differences did not consistently translate into impaired endurance performance, suggesting compensatory mechanisms may mitigate hormonal effects.

Studies in elite athletes further support this interpretation. Antero et al. [18] reported that menstrual cycle phase had little influence on objective performance metrics in elite rowers, despite clear variations in perceived wellness and symptom burden across the cycle. This dissociation highlights the importance of considering both physiological and perceptual factors.

Research examining metabolic responses across the cycle has yielded similarly mixed results. Although estrogen may enhance fat oxidation and glycogen sparing, observed metabolic shifts appear small and of uncertain practical significance for endurance performance [17].

Interpretation is further complicated by variability in how endurance performance is defined and measured. Time-to-exhaustion tests, time trials, and submaximal physiological assessments may differ in their sensitivity to cycle-related effects, contributing to inconsistent findings across studies [10].

As in strength-based performance, individual variability is substantial. Cluster-based and longitudinal analyses reveal that some athletes exhibit consistent patterns across the cycle, whereas others show no discernible relationship between cycle phase and endurance performance [22].

It's also worth noting that the type of endurance activity might matter. Continuous steady-state exercise might be affected differently than high-intensity interval training, and short-duration endurance efforts might show different patterns than prolonged endurance activities. However, we currently lack sufficient research to draw firm conclusions about activity-specific effects.

The role of training adaptation is another important consideration. Some researchers have suggested that well-trained endurance athletes might show smaller cycle-related performance fluctuations than less trained individuals, possibly because training adaptations buffer against hormonal influences. However, this hypothesis remains largely untested, and

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the limited evidence available doesn't provide strong support for it [11].

Mathy et al. [27] examined both maximal and submaximal endurance parameters in elite handball players using oral contraceptives. They found that the oral contraceptive cycle phase had minimal influence on endurance capacity, despite handball's demanding cardiovascular requirements. This adds to the growing body of evidence suggesting that for most athletes, cycle-related endurance performance changes are small or absent.

For practical purposes, this means that while some endurance athletes may benefit from cycle-aware training and competition planning, universal recommendations are probably not appropriate. Individual monitoring - tracking both objective performance and subjective symptoms - offers a more promising approach than assuming all athletes will respond similarly to hormonal fluctuations.

5. Hormonal Contraception and Athletic Performance

Hormonal contraception is widely used among female athletes, with prevalence estimates ranging from 30% to over 60%, depending on the sport and competitive level. These agents fundamentally alter the endogenous hormonal environment, raising important questions about their potential effects on athletic performance.

Combined oral contraceptives (COCs), the most commonly studied form, suppress ovulation and replace cyclical endogenous hormone fluctuations with relatively stable exogenous hormone concentrations during the active pill phase, followed by a hormone-free withdrawal interval. Progestin-only contraceptives generate distinct hormonal profiles, often suppressing ovulation while allowing limited hormonal variability [5].

From the theoretical perspective, hormonal contraception could influence performance in opposing ways. Stabilization of hormone levels may reduce cycle-related variability and facilitate training consistency. Conversely, synthetic hormones differ from endogenous hormones and are typically associated with lower overall hormone concentrations, which could affect neuromuscular function, metabolism, or recovery [12].

Empirical evidence, however, suggests that hormonal contraception does not consistently enhance or impair performance. Cabre et al. [14] reported no meaningful differences in maximal strength or power between naturally cycling women and those using hormonal contraception, despite substantial inter-individual variability. Similar findings have been reported for endurance performance, with studies indicating largely comparable outcomes between users and non-users [16].

The type and formulation of hormonal contraception may matter more than previously recognized. Different COC formulations contain varying doses and types of synthetic hormones, which could have different effects on performance-relevant physiology. Progestin-only contraceptives (pills, implants, or intrauterine devices) create yet another hormonal pattern, often allowing some degree of hormonal fluctuation while suppressing ovulation. Unfortunately, most research has focused on combined oral contraceptives, leaving us with limited evidence about other contraceptive methods [15].

Thompson et al. [19] examined both muscle performance and perceptual measures across the menstrual cycle and oral contraceptive cycle. Interestingly, they found that while objective performance measures showed minimal differences, perceptual measures—including perceived exertion, mood, and symptom burden—differed more substantially. Women using oral contraceptives generally reported fewer negative symptoms than naturally cycling women, particularly during the phases corresponding to menstruation and the late luteal phase. This suggests that contraception's effects on subjective experience might be more significant than its effects on objective performance.

The withdrawal phase of oral contraceptive use (the hormone-free interval) deserves special attention. Some athletes report feeling worse during this phase, experiencing symptoms like premenstrual syndrome despite not having a natural menstrual cycle. Research by Myers et al. [15] is investigating whether this withdrawal phase affects musculoskeletal health and performance, though results are still emerging. Some athletes and clinicians have experimented with continuous or extended-cycle contraceptive regimens (skipping the hormone-free interval) to avoid these withdrawal symptoms, though evidence on performance effects remains limited.

An important consideration is that athletes may choose to use hormonal contraception for reasons beyond contraception itself. Many athletes use these medications to manage menstrual symptoms, regulate cycle timing around competitions, or reduce menstrual bleeding. For athletes who experience significant menstrual symptoms that interfere with training or performance, hormonal contraception might indirectly improve performance by alleviating these

symptoms, even if the hormones themselves have no direct performance-enhancing effects [24].

Humphries et al. [24] studied female collegiate lacrosse players and found that those using hormonal birth control reported fewer performance-limiting menstrual symptoms than non-users. While objective performance metrics didn't differ significantly between groups, the reduced symptom burden in contraceptive users suggests a potential indirect benefit. This highlights the importance of considering both objective performance and subjective experience when evaluating contraceptive effects.

The timing of contraceptive initiation might also matter. Some research suggests that starting hormonal contraception can temporarily affect performance or training responses, possibly due to the body adjusting to the new hormonal environment. However, these effects appear to be transient, with performance typically stabilizing after a few months. This has implications for athletes considering starting or changing contraceptive methods, particularly around important competitive periods [17].

It's also worth noting that hormonal contraception might affect injury risk and recovery, which could indirectly influence performance. Some research has suggested that the stable, lower hormone levels in contraceptive users might affect ligament laxity, bone health, or muscle recovery, though findings have been inconsistent. Fort-Vanmeerhaeghe et al. [26] examined injury risk across the menstrual cycle in adolescent athletes and found complex patterns that differed between contraceptive users and non-users, though more research is needed to understand these relationships fully.

One significant gap in the current evidence is the lack of long-term studies. Most research examines performance over one or a few menstrual or contraceptive cycles, but athletes often use hormonal contraception for years. Whether long-term use has different effects than short-term use remains largely unknown. Similarly, we know little about how starting or stopping hormonal contraception affects performance over time.

Importantly, decisions regarding hormonal contraception should not be driven solely by performance considerations. While performance effects are generally small, contraceptive choice has broader implications for health and personal preference. Current evidence supports an individualized approach, in which potential benefits and drawbacks are weighed collaboratively by athletes and healthcare professionals.

6. Perceptual Symptoms and Psychological Factors

An emerging and increasingly consistent finding in menstrual cycle research is that perceptual symptoms and psychological factors often correlate more closely with performance outcomes than objective hormonal fluctuations. Athletes frequently report symptoms such as fatigue, pain, mood changes, bloating and altered motivation across the menstrual cycle, particularly during menstruation and the late luteal phase. Importantly, these subjective experiences may exert a greater influence on training quality and competitive performance than cycle phase per se [25].

Smith et al. [25] demonstrated that perceived negative menstrual symptoms, rather than changes in estrogen or progesterone concentrations, were associated with impaired cycling race performance. This finding suggests that hormonal fluctuations may influence performance indirectly, through their impact on symptom burden and perception, rather than through direct physiological mechanisms alone.

This pattern has been replicated across multiple studies and sports. Badier et al. [28] used both retrospective questionnaires and daily monitoring to track menstrual cycle and hormonal contraceptive-related symptoms in elite female athletes. They found that symptom burden had a clear impact on well-being and was associated with changes in objective performance metrics. Importantly, the relationship between symptoms and performance was stronger than the relationship between cycle phase and performance, reinforcing the idea that subjective experience is a key mediator.

Several mechanisms may underlie this relationship. Symptoms such as fatigue, pain, or mood disturbances can reduce motivation, alter pacing strategies, and increase perceived exertion during exercise. Even in the absence of measurable changes in physiological capacity, these factors can meaningfully influence performance outcomes [19].

Psychological expectations and beliefs may further modulate performance responses. If athletes anticipate reduced performance during certain cycle phases, these expectations may influence effort regulation, confidence and competitive mindset. While such effects should not be dismissed as purely psychological, they highlight the complex psychophysiological interactions that shape athletic performance [25].

Symptoms may also act as markers of broader physiological or contextual factors including inflammation, inadequate energy availability, or accumulated training stress. In this context, symptom burden re-

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flects not only subjective discomfort but also underlying states that may affect performance capacity [26].

Ratings of perceived exertion (RPE) appear particularly sensitive to cycle-related changes. Several studies report higher RPE during menstruation and the late luteal phase, even when objective performance metrics remain stable. Elevated perceived exertion may lead athletes to unconsciously reduce training intensity or modify pacing, thereby influencing performance over time [21].

Mood and psychological well-being also fluctuate across the cycle in many athletes. Antero et al. [18] observed variations in wellness scores across menstrual phases in elite rowers, despite relatively stable objective performance. This dissociation underscores the importance of psychological well-being alongside physical performance indicators.

The relationship between symptoms and performance appears to be highly individualized. Some athletes experience minimal symptoms and show no cycle-related performance changes. Others experience significant symptoms but maintain stable performance, possibly through effective coping strategies or high motivation. Still others show clear performance decrements associated with symptom burden. Understanding an individual athlete's pattern is crucial for developing effective management strategies [28].

Interestingly, hormonal contraception appears to affect symptom patterns differently than performance. Several studies have found that women using hormonal contraceptives report fewer menstrual symptoms than naturally cycling women, particularly during the phases corresponding to menstruation and the premenstrual period. This symptom reduction might explain why some athletes report better or more consistent performance on contraception, even when objective measurements show minimal differences [19], [24].

This also highlights the importance of individual monitoring. Rather than assuming that all athletes will experience performance changes during specific cycle phases, tracking individual patterns of symptoms and performance can reveal personalized relationships. Some athletes might benefit from adjusting training intensity during high-symptom phases, while others might need psychological support or symptom management strategies. Still others might show no pattern at all and can train without cycle-related modifications [28].

Collectively, these findings indicate that effective management of menstrual cycle considerations should extend beyond hormonal timing alone. Addressing symptom burden, psychological well-being, and individual perceptions may offer greater practical benefit that rigid cycle-based training modifications.

7. Special Considerations for Adolescent Athletes

Adolescent female athletes represent a distinct population with respect to menstrual cycle physiology and its potential implications for athletic performance. During the years following menarche, maturation of the hypothalamic-pituitary-ovarian axis is often incomplete, resulting in irregular cycle length, anovulatory cycles, or transient amenorrhea. Such variability complicates both research design and practical attempts to align with specific menstrual phases [26].

Studies examining adolescent athletes indicate that well-being and symptom burden may fluctuate across the cycle, even when objective performance metrics remain stable. Fort-Vanmeerhaeghe et al. [26] reported heterogeneous patterns of injury risk and well-being across menstrual phases in elite adolescent team sport athletes, underscoring the substantial inter-individual variability present in this population.

A key concern in adolescent athletes is the risk of relative energy deficiency in sport (RED-S), which can disrupt menstrual function and have wide-ranging consequences for bone health, metabolic function and overall well-being. Distinguishing between normal post-menarcheal cycle irregularity and RED-S-related menstrual dysfunction is clinically important but often challenging [4].

Psychosocial factors further influence menstrual experiences in adolescent athletes. Many young athletes report discomfort discussing menstrual issues with coaches or peers, which may limit access to appropriate support. Concerns related to pain, bleeding, or fear of leakage during training and competition can negatively affect confidence, focus, and willingness to participate fully in activities [26]. Education and normalization of menstrual health discussions are therefore essential components of athlete support.

The use of hormonal contraception in adolescent athletes requires particular caution. While such interventions may be prescribed for symptom management or cycle regulation, considerations related to bone development, growth, and long-term reproductive health are especially relevant in this age group. Performance considerations alone should not drive contraceptive decisions [15].

It's also worth noting that adolescent athletes are still developing physically and psychologically. Training responses, recovery capacity, and performance

capabilities are changing as they mature, making it even more challenging to isolate menstrual cycle effects from other developmental factors. What appears to be a cycle-related performance change might actually reflect normal developmental variability or the effects of changing training loads [26].

Despite these challenges, some adolescent athletes do experience significant menstrual symptoms that interfere with training and performance. Dysmenorrhea, heavy menstrual bleeding, and premenstrual symptoms can be particularly disruptive. These symptoms warrant appropriate medical evaluation and management, which might include lifestyle modifications, pain management strategies, or in some cases, hormonal treatments [26].

The limited research specifically examining menstrual cycle effects on performance in adolescent athletes makes it difficult to draw firm conclusions about this population. Most studies have focused on adult athletes, and findings from adult populations may not directly apply to adolescents. This represents an important gap in the literature that deserves attention in future research.

Overall, available evidence supports a flexible and individualized approach when working with adolescent athletes. Emphasis should be placed on education, open communication, monitoring of menstrual health, and early identification of potential health concerns, rather than rigid cycle-based training modifications.

8. Methodological Challenges and Individual Variability

One of the most striking aspects of menstrual cycle research in athletic populations is the inconsistency of findings across studies. While some of this inconsistency likely reflects genuine individual variability in responses, methodological challenges have also contributed significantly to the mixed evidence base. Understanding these challenges is crucial for interpreting existing research and designing better studies in the future.

Perhaps the most fundamental challenge is accurately determining menstrual cycle phase. Many studies rely on calendar-based methods, where participants track their menstrual periods and researchers estimate cycle phase based on cycle day. However, this approach assumes regular cycles and doesn't account for individual variation in cycle length or the timing of ovulation. Even in women with regular cycles, ovulation timing can vary by several days, meaning that calendar-based phase estimation may be inaccurate [7].

More sophisticated approaches use ovulation predictor kits, which detect the luteinizing hormone surge that precedes ovulation. This allows for more accurate identification of the follicular and luteal phases. However, these kits still don't provide information about actual hormone levels, and they require daily testing around the expected ovulation time, which can be burdensome for athletes and researchers [1].

The gold standard for phase verification is direct measurement of hormone levels through blood sampling. However, this approach has its own challenges. Hormone levels fluctuate throughout the day and can be affected by exercise, stress, and other factors. Single time-point measurements may not accurately reflect overall hormonal status. Additionally, frequent blood sampling is invasive, expensive, and may not be practical for many research settings or acceptable to all participants [10].

Another methodological challenge involves the timing and frequency of performance testing. Most studies test performance at discrete time points corresponding to different cycle phases - typically once in the follicular phase and once in the luteal phase, with perhaps additional testing during menstruation. However, this approach may miss more subtle patterns or interactions. Additionally, performance can vary considerably from day to day due to factors unrelated to the menstrual cycle, such as sleep quality, nutrition, stress, and training load. Distinguishing genuine cycle-related changes from normal day-to-day variability requires careful study design and statistical approaches [11].

The choice of performance tests also matters. Different tests may be differentially sensitive to hormonal influences. For instance, maximal strength tests might show different patterns than muscular endurance tests, and time-to-exhaustion tests might be more variable than time trials. Additionally, the ecological validity of laboratory-based performance tests is sometimes questionable - do they truly reflect the complex demands of actual athletic competition? [10]

Sample size is another critical issue. Many studies in this area have relatively small sample sizes, which limits statistical power to detect effects, especially when those effects are small and variable across individuals. Small studies are also more susceptible to chance findings and may not be representative of the broader population of female athletes. Meta-analyses have attempted to address this by combining data across studies, but differences in methodology across studies can make such combinations challenging [1].

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The population studied also affects findings. Most research has focused on recreationally active women or moderately trained athletes, with fewer studies examining elite athletes. Training status might affect hormonal responses, cycle regularity, and performance variability, potentially limiting the generalizability of findings across different athletic populations. Additionally, most studies have focused on young adult women, with limited research on adolescents or masters athletes [8].

Individual variability represents both a methodological challenge and a substantive finding. Across virtually all studies examining menstrual cycle effects on performance, individual responses vary considerably. Some athletes show clear performance patterns across the cycle, others show no pattern, and still others show patterns that differ from the group average. This heterogeneity makes it difficult to draw universal conclusions and suggests that group-level findings may not apply to individual athletes [12].

Several factors might contribute to this individual variability. Genetic differences in hormone receptors or metabolic enzymes could affect individual sensitivity to hormonal fluctuations. Training history, nutritional status, stress levels, and sleep quality might modulate hormonal effects on performance. Psychological factors, including beliefs and expectations about cycle effects, could also contribute to individual differences in responses [25].

The statistical approaches used to analyze menstrual cycle data also present challenges. Traditional statistical methods that compare group means across cycle phases may obscure important individual patterns. Some researchers have advocated for individual-level analyses or case study approaches that examine patterns within individuals rather than averaging across groups. However, these approaches have their own limitations and may not provide the generalizable conclusions that traditional group-level analyses offer [22].

Controlling for confounding variables is another challenge. Many factors that could affect performance-training load, nutrition, sleep, stress, environmental conditions- may vary across the menstrual cycle or across the study period. Distinguishing cycle effects from these other influences requires careful study design and statistical control, which isn't always feasible. Some studies have attempted to standardize these factors, but complete control is rarely possible in real--world athletic settings [18].

The question of blinding also deserves consideration. In most menstrual cycle studies, participants are aware of their cycle phase, which could introduce expectancy effects. True blinding isn't possible in naturally cycling women, though some studies of hormonal contraception have used placebo-controlled designs. The potential for expectancy effects to influence performance is a concern, particularly given the evidence that beliefs and perceptions affect performance outcomes [25].

Finally, there's the challenge of translating research findings into practical recommendations. Even when studies find statistically significant effects, the practical significance of those effects for real-world athletic performance may be limited. Small effect sizes that reach statistical significance in controlled laboratory studies may be overwhelmed by other sources of performance variability in actual training and competition settings [11].

These methodological challenges don't invalidate the existing research, but they do require us to interpret findings cautiously. The inconsistency across studies likely reflects a combination of genuine individual variability, methodological differences, and the inherent challenges of studying complex, multifactorial phenomena like athletic performance. Moving forward, more rigorous methodologies, larger sample sizes, individual-level analyses, and attention to both objective and subjective outcomes will help clarify the relationship between menstrual cycle and athletic performance.

9. Discussion

After reviewing the current evidence on menstrual cycle effects on athletic performance, several key themes emerge that warrant careful consideration. Perhaps most importantly, the relationship between hormonal fluctuations and performance is far more complex and individualized than early research suggested. The simple notion that certain cycle phases universally enhance or impair performance doesn't hold up under scrutiny.

The evidence consistently shows that group-level effects of menstrual cycle phase on performance are generally small and often statistically non-significant. This pattern holds across both strength/power and endurance performance domains. When significant effects are detected, they're typically subtle - often within the range of normal day-to-day performance variability. This doesn't mean that cycle effects don't exist, but it does suggest that for many athletes, menstrual cycle phase is not a major determinant of performance capacity [1], [16].

However, this group-level conclusion masks substantial individual variability. Some athletes clearly do experience performance fluctuations across their cycle, while others show no discernible pattern. This heterogeneity is one of the most consistent findings across studies and has important practical implications. It suggests that universal, cycle-based training recommendations are unlikely to be appropriate for all athletes. Instead, individualized approaches based on personal monitoring and experience are more likely to be beneficial [12], [22].

One of the most intriguing findings from recent research is that perceptual symptoms and psychological factors often correlate more strongly with performance than objective hormonal measurements. Athletes' subjective experiences - including fatigue, mood, perceived exertion, and symptom burden - frequently predict performance better than cycle phase or hormone levels alone. This observation challenges purely physiological models of cycle effects and highlights the importance of considering the whole athlete, not just their hormonal status [25], [28].

This finding also has important implications for intervention strategies. If symptoms and perceptions are key mediators of cycle effects on performance, then interventions targeting symptom management, psychological support, and coping strategies might be more effective than rigid cycle-based training modifications. This could include strategies like pain management for dysmenorrhea, psychological skills training to maintain motivation and confidence despite symptoms, or lifestyle modifications to reduce symptom burden [19], [26].

The role of hormonal contraception adds another layer of complexity. Current evidence suggests that hormonal contraceptives don't universally impair or enhance performance, though they may reduce menstrual symptoms and cycle-related variability for some athletes. The decision to use hormonal contraception should be individualized, considering not just potential performance effects but also symptom management, contraceptive needs, side effects, and personal preferences. Performance considerations, when they exist, are generally small and should be weighed alongside these other factors [14], [24].

The methodological challenges in this research area cannot be overlooked. Difficulties in accurately determining cycle phase, controlling for confounding variables, distinguishing cycle effects from normal performance variability, and accounting for individual differences have all contributed to the inconsistent findings across studies. Future research would benefit from more rigorous methodologies, including direct hormonal verification, larger sample sizes, individual-level analyses, and attention to both objective performance and subjective experiences [7], [10].

It's also worth considering what we don't know. Most research has focused on young adult athletes, leaving gaps in our understanding of adolescent and masters athletes. We know relatively little about long-term effects of hormonal contraception on performance or about how starting or stopping contraception affects athletic capacity over time. The mechanisms underlying individual variability in cycle responses remain poorly understood. And we have limited evidence about how cycle effects might differ across different sports, training phases, or competitive levels [15], [26].

The disconnect between athletes' experiences and research findings deserves attention. Many athletes report feeling that their cycle affects their performance, yet research often fails to detect consistent group-level effects. This doesn't mean athletes' experiences are invalid—rather, it highlights the importance of individual variability and the role of subjective factors. It also suggests that researchers and practitioners need to take athletes' self-reported experiences seriously, even when they don't align perfectly with group-level research findings [28].

From a practical standpoint, the current evidence supports a flexible, individualized approach to managing menstrual cycle considerations in athletic training and competition. Rather than implementing universal cycle-based training modifications, athletes and coaches should consider individual monitoring to identify personal patterns. For athletes who do experience cycle-related performance changes or symptoms, targeted interventions can be developed based on their specific patterns and needs [18], [22].

This individualized approach requires good communication between athletes, coaches, and sports medicine professionals. Creating environments where athletes feel comfortable discussing menstrual health and cycle-related concerns is essential. Education about normal menstrual function, what constitutes problematic symptoms, and available management strategies can empower athletes to make informed decisions about their training and health [26].

It's also important to maintain perspective about the magnitude of cycle effects relative to other factors affecting performance. Training load, nutrition, sleep, stress, recovery, and psychological factors all significantly influence athletic performance. For most athletes, optimizing these factors is likely to have a larger impact on performance than cycle-based modifications. The menstrual cycle should be considered as

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one factor among many, not as the primary determinant of performance capacity [11].

The research also highlights the importance of overall menstrual health. While cycle phase may have limited effects on performance for many athletes, menstrual dysfunction - including irregular cycles, amenorrhea, or severe symptoms - can indicate underlying health issues that warrant attention. Monitoring menstrual health as part of overall athlete health surveillance is important, not just for performance optimization but for long-term health and well-being [4], [26].

Looking forward, the field would benefit from moving beyond the question of whether cycle effects exist toward understanding for whom they exist, under what circumstances, and through what mechanisms. Research designs that embrace individual variability rather than treating it as noise, that consider both physiological and psychological factors, and that examine real-world athletic performance rather than just laboratory tests, will likely provide more actionable insights [22], [28].

10. Future Directions and Recommendations

The current evidence base highlights the need to move beyond generalized, group-level comparisons toward research designs that better capture individual variability. Future studies should prioritize within-subject and n-of-1 approaches, which may provide meaningful insights into how menstrual cycle phases influence performance in specific athletes rather than average effects across heterogeneous groups [22].

Methodological rigor remains a critical priority. Direct hormonal verification should be incorporated where feasible, alongside repeated performance assessment across the cycle. Greater attention should be given to potential confounding variables such as training load, sleep quality, nutritional status, and psychological stress, and environmental conditions, all of which may interact with hormonal fluctuations [7], [10].

Perceptual symptoms and psychological factors warrant further investigation, particularly as potential mediators between hormonal changes and performance outcomes. Further research should explore whether investigations targeting symptom management, perceived exertion, or psychological well-being can mitigate cycle-related performance variability [25], [28].

Research on hormonal contraception should expand beyond combined oral contraceptives to include progestin-only formulations, hormonal IUDs, implants, and patches. Different contraceptive methods create different hormonal environments and may have different effects on performance and symptoms [16]. Long-term studies examining how extended contraceptive use affects performance, training adaptations, and health outcomes would fill an important gap. Additionally, research on the transition periods when starting or stopping contraception could inform timing recommendations around important competitive periods [18].

Special populations remain underrepresented in the literature. Adolescent athletes, masters athletes, and individuals transitioning through perimenopause or menopause may exhibit distinct hormonal profiles and performance responses that are not captured in studies of young adult women [26].

The mechanisms underlying cycle effects on performance remain incompletely understood. Research examining the physiological pathways through which hormones might affect muscle function, metabolism, thermoregulation, and other performance-relevant systems would help clarify when and why cycle effects occur. This mechanistic understanding could inform more targeted interventions and help predict which athletes might be most susceptible to cycle-related performance changes [2], [3].

Greater emphasis should also be placed on ecological validity. Laboratory-based tests, while valuable, may not fully reflect real-world athletic performance. Advances in wearable technology and longitudinal monitoring offer promising opportunities to study performance, symptoms, and training responses in natural training environments [18], [22].

Intervention studies represent a major gap in the current literature. Randomized controlled trials examining cycle-informed training strategies, symptom management approaches, psychological support strategies, or nutritional interventions are needed to translate observational findings into actionable recommendations [19].

From a practical standpoint, research should inform the development of evidence-based monitoring tools and decision-support systems. Apps or other technologies that help athletes track their individual patterns of symptoms and performance across the cycle, identify personal relationships, and receive personalized recommendations could translate research findings into actionable strategies. However, such

tools should be developed based on solid evidence and validated in athletic populations [28].

Education and implementation research is also needed. Even when evidence exists, it's not always effectively translated into practice. Research examining how to effectively educate athletes, coaches, and sports medicine professionals about menstrual cycle effects, how to create supportive environments for discussing menstrual health, and how to implement individualized monitoring and management strategies would help bridge the research-practice gap [26].

Finally, interdisciplinary collaboration will be critical to advancing this field. Integrating perspectives from exercise physiology, endocrinology, psychology, sports medicine and data science is likely to yield more comprehensive and practically relevant insights into the complex relationship between menstrual cycle physiology and athletic performance.

11. Conclusions

The relationship between menstrual cycle and athletic performance is far more nuanced than early research suggested. After reviewing current evidence, several key conclusions emerge that should inform both research and practice in this area.

First, group-level effects of menstrual cycle phase on performance are generally small and inconsistent. While some studies have reported significant differences in strength, power, or endurance performance across cycle phases, many others have found minimal or no effects. When effects are detected, they're typically subtle – often within the range of normal day-to-day performance variability. This pattern holds across different types of athletic performance and different populations of athletes.

However, this group-level conclusion doesn't tell the whole story. Individual variability is substantial and consistent across studies. Some athletes clearly experience performance fluctuations across their cycle, while others show no discernible pattern. This heterogeneity is perhaps the most important finding from recent research, as it suggests that universal recommendations are unlikely to be appropriate for all athletes.

Perceptual symptoms and psychological factors have emerged as potentially more important than hormonal fluctuations alone. Athletes' subjective experiences – including fatigue, mood, perceived exertion, and symptom burden – often correlate more strongly with performance than cycle phase or hormone levels. This highlights the importance of considering the whole athlete, not just their hormonal status, and suggests that interventions targeting symptoms and psychological well-being may be more effective than rigid cycle-based training modifications.

Hormonal contraception appears to have minimal direct effects on performance for most athletes, though it may reduce menstrual symptoms and cycle-related variability. Decisions about contraceptive use should be individualized, considering symptom management, contraceptive needs, side effects, and personal preferences alongside any potential performance effects. Current evidence doesn't support avoiding hormonal contraception solely for performance reasons, nor does it suggest that contraception universally enhances performance.

The methodological challenges in this research area are significant and have contributed to inconsistent findings across studies. Difficulties in accurately determining cycle phase, controlling for confounding variables, and accounting for individual differences all complicate interpretation of existing evidence. Future research with more rigorous methodologies, larger sample sizes, and attention to individual variability will help clarify these relationships.

From a practical standpoint, the current evidence supports a flexible, individualized approach rather than universal cycle-based training modifications. Athletes and coaches should consider individual monitoring to identify personal patterns of symptoms and performance. For athletes who do experience cycle-related changes, targeted interventions can be developed based on their specific patterns and needs. Creating supportive environments where athletes feel comfortable discussing menstrual health is essential for implementing such individualized approaches.

It's important to maintain perspective about the magnitude of cycle effects relative to other factors affecting performance. Training load, nutrition, sleep, recovery, and psychological factors all significantly influence athletic performance. For most athletes, optimizing these factors is likely to have a larger impact than cycle-based modifications. The menstrual cycle should be considered as one factor among many, not as the primary determinant of performance capacity.

Looking forward, research should move beyond asking whether cycle effects exist toward understanding for whom they exist, under what circumstances, and through what mechanisms. Embracing individual variability, examining both physiological and psychological factors, and studying real-world athletic performance will provide more actionable insights than

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continued group-level comparisons in laboratory settings.

Ultimately, the goal should be supporting female athletes' overall health, well-being, and performance through evidence-based, individualized approaches. This requires good communication between athletes, coaches, and sports medicine professionals, along with continued research to fill existing knowledge gaps. While we've made progress in understanding menstrual cycle effects on athletic performance, much remains to be learned. The complexity and individuality of these relationships demand nuanced, personalized approaches rather than one-size-fits-all recommendations.

By acknowledging both what we know and what we don't know, by taking athletes' experiences seriously while maintaining scientific rigor, and by focusing on practical, individualized solutions rather than universal prescriptions, we can better support female athletes in achieving their performance goals while maintaining their health and well-being.

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