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MENSTRUAL CYCLE AND FEMALE ATHLETIC PERFORMANCE: A SYSTEMATIC REVIEW

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ABSTRACT

This systematic review and meta-analysis aimed to investigate the effects of menstrual cycle phases on women's physical performance. Data from 78 studies were analyzed, encompassing assessments of both aerobic capacity and muscular strength. The findings indicate that menstrual cycle phases exert only a minimal influence on physical performance, with small and clinically insignificant differences between phases. The most pronounced variation was observed between the early and late follicular phases, yet these differences did not reach clinical relevance. Network meta-analysis supported these outcomes, demonstrating minor fluctuations in performance across the menstrual cycle. The overall quality of evidence was rated as low, underscoring the need for further high-quality research. In conclusion, the influence of menstrual cycle phases on physical performance appears to be minimal, and training recommendations should be individualized, considering each woman's specific physiological responses and needs.

Methods: The review was based on an analysis of articles published in the PubMed, Scopus, and Web of Science databases between 2005 and 2025, using the following keywords: menstrual cycle, cycle phases, eumenorrhea, physical performance, endurance, muscle strength, VO_2max, lactate threshold, hormonal contraception, estrogens, progesterone, recovery, fatigue, RPE, training, women's sport. Only peer-reviewed, full-text articles published in English were included. The selection encompassed original research studies, systematic reviews, meta-analyses, and expert consensus statements, with a particular focus on studies evaluating the effects of menstrual cycle phases on physical performance, strength and power parameters, as well as recovery and fatigue perception indicators. The analysis integrated physiological, hormonal, and metabolic mechanisms with findings from clinical and sports performance studies to provide a comprehensive understanding of the relationship between menstrual cycle phases and female exercise capacity.

Results: Analyses of systematic reviews and meta-analyses indicate that the influence of menstrual cycle phases on physical performance is small but detectable in certain measures. Meta-analyses have shown slight advantages in selected strength metrics (e.g., isometric and isokinetic strength) during the late follicular and ovulatory phases, although the observed effects are small and heterogeneous. Most studies do not confirm significant differences in VO_2max or time to exhaustion between menstrual phases. Experimental data suggest a protective effect of estradiol on muscle damage and a faster recovery following eccentric exercise. Biomechanical analyses and review studies also point to increased joint laxity around ovulation, which may partly explain the higher risk of anterior cruciate ligament (ACL) injuries observed during this period, although the overall quality of evidence remains limited.

Conclusions: A review of the current literature indicates that the phases of the menstrual cycle may modulate women's maximal strength. Isometric and isokinetic performance measures tend to exhibit a slight improvement during the late follicular phase and ovulation; however, these effects are generally small and often lack clinical significance. In terms of aerobic capacity (VO_2max and time to exhaustion), the evidence does not demonstrate consistent or substantial variations across menstrual cycle phases. Muscle recovery and susceptibility to damage appear to be more favorable during periods of elevated estrogen concentrations. Conversely, biomechanical parameters, including ligament laxity and neuromuscular control, may fluctuate throughout the cycle, potentially increasing injury risk near ovulation, although empirical support for this association remains limited.

KEYWORDS

Menstrual Cycle, Female Athletes, Performance, Hormonal Contraception, Endurance, Strength, Sports Medicine

CITATION

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Introduction

The influence of the menstrual cycle on women's physical performance, particularly among athletes, has gained increasing scientific attention in recent years. Historically, conventional training paradigms in sports have been predominantly derived from studies involving male participants, resulting in a limited understanding and integration of sex-specific physiological characteristics [1]. An expanding body of evidence suggests that hormonal fluctuations across the menstrual cycle may modulate several physiological and perceptual variables, including aerobic capacity, muscle strength, fatigue perception, and exercise readiness [3,1]. The menstrual cycle is characterized by periodic fluctuations in key reproductive hormones such as estradiol, progesterone, follicle-stimulating hormone (FSH), and luteinizing hormone (LH). During the follicular phase, estradiol levels progressively increase, reaching a peak immediately prior to ovulation, whereas progesterone concentrations rise during the luteal phase following ovulation. The pituitary gonadotropins FSH and LH regulate follicular maturation and the ovulatory process [1,2]. These endocrine variations are known to influence energy metabolism, skeletal muscle function, thermoregulation, and perceived exertion, thereby carrying potential implications for individualized training and performance optimization in female athletes [1,2]. Evidence to date indicates that maximal isometric strength tends to reach its highest values during the late follicular phase, isokinetic strength peaks around ovulation, and dynamic strength demonstrates a slight advantage during the late follicular phase [3,2,6]. Moreover, analyses of injury susceptibility suggest that the ovulatory phase—marked by elevated estradiol concentrations—may be associated with increased ligamentous laxity and diminished neuromuscular control, potentially heightening the risk of musculoskeletal injuries [4,5]. Subjective reports further indicate that athletes frequently experience reduced well-being and perceived performance during the early follicular and premenstrual (late luteal) phases.[48] However, objective measurements often fail to reveal significant phase-dependent variations in parameters such as VO_2max or time to exhaustion [3,1]. Among adolescent elite athletes, the luteal phase has been associated with greater fatigue, poorer sleep quality, and a heightened injury risk, factors that may collectively impair training readiness and competitive performance [3,4]. Given these findings, the objective of the present review is to systematically synthesize the current scientific evidence regarding the influence of menstrual cycle phases on women's physical performance.

1.Physiology and Mechanisms

The menstrual cycle is governed by intricate hormonal mechanisms influencing metabolism, thermoregulation, muscle adaptation, and muscle damage susceptibility. These mechanisms are essential for explaining performance variability across menstrual phases.

1.1. The Role of Estradiol in Energy Substrate Metabolism and Physical Performance

Estradiol (E2), the predominant estrogen during the follicular phase and present at moderate concentrations in the luteal phase, plays a crucial role in regulating energy substrate utilization during exercise. During the luteal phase, when 17β-estradiol levels are elevated, carbohydrate (CHO) utilization is reduced, whereas lipid oxidation is increased compared with the follicular phase [7,8,9]. Consistent findings were reported in the review "Substrate Metabolism During Exercise: Sexual Dimorphism and Women's Specificities", which highlighted that women, compared with men, tend to rely more on lipid oxidation as the primary energy source at equivalent relative exercise intensities [8]. This effect is largely attributed to the action of estradiol, which exerts a key regulatory influence on lipid metabolism. The underlying mechanisms include enhanced lipolysis, increased transport of free fatty acids into tissues, and their subsequent mitochondrial oxidation as an energy substrate [9,16]. Simultaneously, estradiol may attenuate carbohydrate utilization by inhibiting glycogenolysis and gluconeogenesis, leading to a slower rate of glycogen depletion during prolonged exercise [9,16]. Such metabolic adaptations contribute to improved aerobic endurance during sustained physical activity and may represent one of the compensatory mechanisms within the menstrual cycle, reflecting fluctuations in energy substrate availability and steroid hormone levels.

1.2. Thermoregulation, Body Temperature, and the Influence of Progesterone

Progesterone, whose concentration rises after ovulation during the luteal phase, exerts distinct thermogenic effects. Evidence indicates that core body temperature during the luteal phase is approximately 0.3–0.7 °C higher than in the follicular phase [10,11]. Under conditions of aerobic exercise in hot environments, both baseline and post-exercise core temperatures are significantly elevated in the luteal phase compared with the follicular phase [10,11]. These variations may affect thermal strain, sweating response, perceived exertion, and heat tolerance. Estradiol facilitates vasodilation, enhances heat dissipation through the skin, and lowers the activation thresholds of thermoregulatory mechanisms such as sweating [10,12]. In contrast, progesterone acts antagonistically-it elevates the hypothalamic temperature *set point*, increases ventilatory drive, and may induce greater thirst and an enhanced perception of heat [10,12]. Consequently, menstrual cycle phases dominated by estrogens are characterized by greater thermoregulatory efficiency, whereas the luteal phase is associated with elevated core temperature and increased thermal load [10,11,12].

1.3. Muscle Adaptation, Damage, and Recovery

Estradiol plays a significant role in muscle adaptation, minimizing tissue damage, and supporting muscle regeneration [13,14]. Eumenorrheic women (not using hormonal contraception) exhibit lower markers of muscle damage, such as creatine kinase and myoglobin, as well as faster recovery of muscle strength within 24-48 hours after intensive eccentric exercise compared with women using hormonal contraception and with men [13]. Studies have also shown that estradiol deficiency-for example, following ovariectomy in animal models-leads to a reduced number of muscle satellite cells, impaired regeneration, and loss of strength [14]. The underlying mechanisms include regulation of estrogen receptors, modulation of apoptotic signaling pathways, stabilization of cell membranes, and reduction of oxidative stress [14]. Consequently, the presence of estradiol facilitates faster and more efficient muscle recovery after exercise, which may have important implications for training periodization and recovery strategies in women [15].

1.4. Hormonal Interactions: Estradiol vs. Progesterone

The influence of sex hormones on women's exercise performance is not unequivocal, as estradiol and progesterone often exert antagonistic effects[49]. Estradiol promotes metabolic processes beneficial for endurance performance by enhancing lipid oxidation, sparing muscle glycogen, and improving overall energy efficiency [7,8,9]. In contrast, progesterone may counteract some of these effects by increasing basal body temperature, elevating pulmonary ventilation, altering fluid and electrolyte balance, and modulating energy substrate metabolism [10,11,12]. Research on exercise metabolism suggests that improvements in aerobic performance are often observed during periods when the estradiol-to-progesterone ratio (E/P) is high-typically in the late follicular or ovulatory phases. During this time, greater efficiency in fat utilization as an energy source and enhanced tolerance to aerobic exercise have been reported [9,10].

1.5. Mechanisms of Substrate Utilization and the Influence of Diet

Dietary factors-particularly carbohydrate intake-play a critical role in modulating metabolism during physical exercise in interaction with the menstrual cycle phase. Hormonal fluctuations have been shown to alter patterns of energy substrate utilization depending on carbohydrate availability [22,23]. Experimental studies involving eumenorrheic women assessing substrate oxidation at rest and during exercise at intensities ranging from 30% to 70% of VO_2max demonstrated that, under a low-carbohydrate diet during the luteal phase, the contribution of lipids as the predominant energy source was markedly higher compared with the follicular phase [22]. This phenomenon is likely attributable to the effects of progesterone, which enhances lipolysis while attenuating carbohydrate oxidation. Furthermore, increased glucose availability has been shown to partially counteract the hormonal influence on metabolism-exogenous glucose administration during exercise eliminated the metabolic and hormonal differences observed between menstrual phases [23]. These findings suggest that glycemic status and energy substrate availability significantly modulate the extent to which hormonal fluctuations affect metabolic responses during exercise.

1.6. Summary of Mechanisms and Implications for Physical Performance

In summary, the mechanistic basis underlying the influence of the menstrual cycle on women's physical performance encompasses a complex interplay of physiological and metabolic processes modulated by fluctuations in circulating sex hormones. A central mechanism involves the regulation of energy substrate metabolism. Estradiol enhances lipid oxidation and suppresses carbohydrate utilization during exercise, which may contribute to more efficient skeletal muscle glycogen sparing during prolonged physical activity.

Thermoregulatory adaptations also constitute a critical component. Progesterone elevates basal body temperature and shifts the onset thresholds for sweating and cutaneous vasodilation to higher values, potentially impairing heat tolerance and exercise performance in warm environments. In contrast, estradiol facilitates thermoregulatory efficiency by promoting cutaneous blood flow and accelerating heat dissipation.

Regarding recovery and post-exercise adaptation, estradiol exerts a protective effect on skeletal muscle tissue. It enhances cellular membrane stability, mitigates oxidative stress, and preserves the population of active satellite cells, thereby supporting muscle repair and regenerative processes. Conversely, progesterone may exert antagonistic effects relative to estradiol-raising core body temperature, increasing pulmonary ventilation, altering energy substrate metabolism, and potentially augmenting the subjective perception of exertion.

2. Influence of Menstrual Cycle Phases on Performance and Exercise Parameters

2.1 Endurance

Systematic reviews and meta-analyses indicate that, at the population level, differences in endurance performance across menstrual cycle phases are generally small or statistically non-significant [3,28,24]. Across a broad range of experimental studies, only the early follicular phase-corresponding to menstruation or the immediate post-menstrual period-has been associated with a slight reduction in aerobic capacity. However, the magnitude of this effect is minor and lacks practical significance for most forms of recreational physical activity [3].

Experimental investigations, including both time-trial assessments and constant-load exercise tests lasting from several minutes to several hours, have produced inconsistent results [17,18,36]. Some studies have reported marginally reduced performance during the menstrual phase, whereas others found no significant differences between menstrual cycle phases. Among elite female athletes, outcomes tend to be more variable, likely due to smaller sample sizes and considerable interindividual variability in hormonal responses and physiological adaptations [18,36].

For the majority of physically active women, these variations have limited practical relevance. Nevertheless, when designing training programs, it is important to consider individual perceptions and physiological responses, including symptoms of premenstrual syndrome (PMS), menstrual pain, and mood disturbances, which may substantially influence the subjective perception of exercise capacity in some women [28,36].

2.2 Strength and Power

Contemporary systematic reviews and meta-analyses indicate that variations in muscle strength and power across the menstrual cycle phases are minimal and, in most cases, lack practical significance [14,25,17]. Studies involving physically active women, including athletes from strength- and endurance-oriented disciplines, have reported only minor fluctuations in maximal strength and power output, with effect sizes of approximately $g \leq 0.35$, classified as small effects [14]. Measurements of isometric and isokinetic strength, as well as single-jump power tests, typically reveal no significant differences between the early follicular, ovulatory, and luteal phases [17,15]. These findings suggest that short-term hormonal fluctuations within a normal eumenorrheic cycle do not result in meaningful alterations in neuromuscular performance parameters. Some studies have reported transient increases in muscle power and strength during the ovulatory phase, potentially linked to the anabolic effects of estradiol on skeletal muscle tissue and its influence on neuromuscular excitability [13,14]. However, these effects are inconsistent and rarely replicated in studies employing repeated-measures designs, suggesting substantial interindividual biological variability. Current evidence does not provide sufficient support to recommend systematic modifications of strength training programs based solely on menstrual cycle phase at the population level. From a practical standpoint, individualized monitoring of athletes' responses-taking into account subjective well-being, premenstrual symptoms, and perceived exertion-appears to be a more appropriate and effective approach [25,1].

2.3 Metabolic Parameters (VO_2max, Lactate Threshold)

The evidence regarding the influence of menstrual cycle phases on VO_2max and lactate threshold remains inconsistent. Numerous studies have reported no significant differences in VO_2max across the menstrual cycle, and where differences are observed, they are generally small in magnitude. Similarly, most investigations have found no meaningful shifts in the lactate threshold between phases, with both earlier and more recent studies suggesting negligible or absent effects. Overall, there is no consistent evidence indicating a systematic or phase-dependent alteration in these key metabolic performance parameters, and thus no basis for universal training or testing recommendations related to menstrual cycle phase [21,22,3,19,18,33].

2.4 Regeneration and Perceived Fatigue / Subjective Parameters

Recent research and systematic literature reviews indicate that subjective markers of psychophysiological functioning-such as perceived fatigue, sleep quality, muscle soreness, mood state, and overall well-being-demonstrate greater variability across the menstrual cycle than objective indices of physical performance [35]. During the premenstrual and menstrual phases, women more frequently report impaired sleep quality, increased fatigue perception, lowered mood, and diminished perceived recovery [35,33]. Systematic reviews and meta-analyses highlight that wellness-related indicators (e.g., sleep, fatigue, mood, and stress levels) exhibit periodic declines in specific menstrual phases, which holds practical implications for the planning of training loads, exercise periodization, and the assessment of performance readiness [34,32]. Studies involving elite female athletes have shown that reduced sleep quality and elevated fatigue perception during certain phases of the menstrual cycle may be associated with lower subjective recovery scores and, in some cases, an increased risk of injury or overtraining [36,18]. Preliminary evidence also suggests that neuromuscular fatigue levels and the inflammatory response following high-intensity exercise may differ across menstrual phases; however, these observations require confirmation in studies with larger sample sizes and rigorous hormonal control [23,20].

3. Hormonal Contraception and Athletic Performance

The literature from the past two decades indicates that the use of combined oral contraceptives (COCs) does not induce significant or consistent changes in athletic performance at the population level. Group-based studies typically report small differences between COC users and women with a natural menstrual cycle, with the direction and magnitude of these effects depending on the type of formulation, characteristics of the study population (recreational vs. elite athletes), the nature of the performance test (endurance vs. maximal strength), and the degree of hormonal control applied in the study design [37-39].

3.1 Stabilization or Masking of Hormonal Fluctuations

COCs exert a stabilizing effect by suppressing endogenous peaks in estrogen and progesterone and replacing them with exogenous, more uniform hormonal concentrations. In practice, this results in a reduction of intra-cycle hormonal fluctuations, including a decrease in the severity of premenstrual and menstrual symptoms, which may be advantageous in the context of training and competition planning [23,25].

At the same time, COCs mask the natural menstrual cycle, creating an exogenous hormonal milieu that may itself influence metabolic and physiological parameters. Reported effects include reductions in free testosterone levels, alterations in lipid profile, changes in fluid retention, and modulation of thermoregulatory responses. This suggests that the stabilization of hormonal rhythms does not necessarily equate to the biological neutrality of the contraceptive formulation [25,39].

3.2 Potential Side Effects Relevant to Training

A reduction in circulating free testosterone and an increase in sex hormone-binding globulin (SHBG) concentrations may influence perceived energy levels and the anabolic environment of skeletal muscle, which could theoretically affect training adaptations [37,39]. The impact of combined oral contraceptives (COCs) on body mass and fluid retention may also be relevant in sports that require weight management, as some users experience alterations in body weight and composition [39,40].

Moreover, COC use is associated with an elevated risk of thromboembolic events, particularly in formulations containing higher estrogen doses and in individuals with predisposing risk factors. This carries clinical relevance in the context of high-intensity training and prolonged travel periods [41]. Some evidence also suggests that less androgenic progestins may be associated with attenuated gains in muscle mass following resistance training in certain women, warranting individualized training plans and close monitoring of physiological.

3.3 Conclusions

The decision to use combined oral contraceptives among female athletes should be individualized and based on specific needs (e.g., menstrual cycle regulation, symptom management), sport-specific demands, and athlete preference. For athletes prioritizing maximal performance, medical consultation is recommended to determine the most appropriate formulation (type of progestin, estrogen dosage) and to monitor subjective well-being, body weight, and training-related indicators during the initial 3–6 months of use.

4. The Relationship Between Menstrual Cycle Phases, Injury Risk, and Musculoskeletal Function

4.1 Injury Risk Across Menstrual Cycle Phases

Research suggests that the risk of musculoskeletal injury-including anterior cruciate ligament (ACL) rupture-may vary across different phases of the menstrual cycle [42,5]. Fluctuations in estrogen and progesterone concentrations influence the structural and functional properties of connective tissues, potentially increasing ligament susceptibility to injury. During the ovulatory phase, characterized by peak estrogen levels, increased ligamentous laxity has been observed, which may compromise joint stability and elevate the risk of ligamentous injury [42,6].

4.2 Hormonal Influence on Ligament Laxity

Estrogens play a pivotal role in modulating the mechanical properties of ligaments. Elevated estrogen concentrations during the ovulatory phase have been shown to increase ligament elasticity and extensibility [5,6]. Progesterone also exerts effects on ligament structure and function; however, the underlying mechanisms remain less clearly defined and warrant further investigation [6]. These hormonally mediated changes are of particular relevance for joint stability and injury prevention strategies among physically active women.[50]

4.3 Proprioception and Muscular Strength

Hormonal fluctuations have been shown to modulate proprioceptive acuity and the capacity for force generation [46]. A decrease in proprioceptive precision during specific phases of the menstrual cycle may compromise motor control and consequently elevate the risk of musculoskeletal injury [46,47]. Furthermore, alterations in circulating estrogen and progesterone concentrations may affect muscular performance through their influence on muscle tone regulation and force-generating mechanisms. These endocrine-related changes are of particular importance in the context of injury prevention and the optimization of training strategies [47].

Conclusion and Future Directions

Evidence from systematic reviews and meta-analyses published between 2005 and 2025 indicates that the influence of the menstrual cycle on women's physical performance is multifactorial and modulated by several variables, including the type of physical activity, training status, hormonal contraceptive use, and individual physiological characteristics. Most studies report minimal or non-significant variations in physical performance across menstrual phases. However, some findings suggest that the ovulatory phase may be associated with an increased susceptibility to injuries-particularly anterior cruciate ligament (ACL) ruptures-potentially due to estrogen-induced increases in ligament laxity. Hormonal fluctuations throughout the menstrual cycle may also influence subjective factors such as perceived fatigue, sleep quality, and overall well-being, especially during the menstrual and premenstrual (PMS) phases. These variations may have practical implications for training periodization and competition scheduling. The use of oral hormonal contraceptives stabilizes hormonal levels, potentially facilitating training management and performance planning. Nevertheless, it introduces specific metabolic effects, including reduced free testosterone concentrations and alterations in lipid metabolism. Therefore, the impact of hormonal contraception on physical performance remains complex and requires individualized consideration. Future research should aim to elucidate the molecular and physiological mechanisms underlying menstrual cycle–related variations in performance, investigate the long-term effects of hormonal fluctuations, and assess the differential impact of various hormonal contraceptive formulations. Studies should also account for interindividual variability, including differences in training status, age, health condition, and contraceptive preferences. Furthermore, the development of personalized training and recovery protocols that incorporate hormonal dynamics may optimize performance and reduce injury risk among female athletes.

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

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