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THE INFLUENCE OF MENSTRUAL CYCLE PHASES ON ATHLETIC PERFORMANCE IN WOMEN

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ABSTRACT

Introduction: The menstrual cycle, driven by fluctuations in ovarian and pituitary hormones, has profound effects on women's physiology, psychology, and performance. The aim of this review was to examine the relationship between the phases of the menstrual cycle and women's well-being, physical activity, and cognitive function. The follicular, ovulatory, and luteal phases were analyzed with respect to hormonal profiles and their impact on exercise tolerance, fatigue, thermoregulation, injury risk, mood, and concentration. Literature indicates that during the early follicular phase, when estrogen and progesterone levels are low, women often experience reduced energy levels and increased discomfort, which may limit physical performance. In contrast, the late follicular and ovulatory phases, characterized by rising estrogen, are associated with improved endurance, strength, and motivation, suggesting a performance advantage. However, the luteal phase, dominated by progesterone, is linked to thermoregulatory challenges, increased fatigue, and greater susceptibility to injuries. Beyond physical outcomes, hormonal changes also influence psychological states, including mood swings, irritability, and concentration difficulties, which may negatively affect academic and professional productivity. Importantly, interindividual variability remains high, and not all women experience the same symptoms or limitations. Awareness of cycle-dependent changes is crucial for tailoring training plans, optimizing recovery, and supporting mental health.
Aim of the study: The aim of this thesis is to provide an overview of the menstrual cycle and to analyse its impact and accompanying hormonal fluctuations on athletic performance in women.
Material and Methods: The review was based on the analysis of materials collected in the databases PubMed, Google Scholar, Scopus, books and other scientific articles from the last 15 years, but most of the information in this review comes from papers published after 2019.
Conclusions: Recognition of menstrual cycle phases is critical for personalized approaches in medicine, sport, and lifestyle planning. By integrating knowledge of hormonal influences into training schedules, recovery strategies, and mental health support, women can improve performance and well-being. The menstrual cycle should therefore be considered not merely a biological process but a key determinant of women's holistic health and efficiency.

KEYWORDS

Menstrual Cycle and Sport, Menstrual Cycle and Exercises, The Impact of Menstrual Cycle on Strength Performence, The Influence of Female Hormones on the Body, Menstrual Cycle and Recovery

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Introduction

Menstrual cycle

The female reproductive system differs significantly from the male, as it undergoes cyclical changes that prepare the body for ovulation and the possibility of pregnancy. This process is known as the menstrual cycle. An important part of this cycle is menstruation, or bleeding, during which the lining of the uterus is shed under the influence of hormones produced by the hypothalamus, pituitary gland, and ovaries. The first menstruation, called menarche, usually occurs during puberty, at around the age of 12, while bleeding ceases at menopause, which typically begins at about 51 years of age. [1,2]

The length of the menstrual cycle is the number of days between the first day of menstrual bleeding of one cycle and the beginning of the next cycle. The median duration of a menstrual cycle is 28 days, with most cycles lasting between 25 and 30 days. During the cycle, there are two phases: the follicular (proliferative) phase and the luteal (secretory) phase during which there are rhythmic fluctuations of the four female sex hormones: oestrogen, progesterone, folliculotropic hormone (FSH) and luteinising hormone (LH) [4]. In a healthy woman, during the follicular phase beginning with the first day of bleeding, oestrogen levels initially remain low (early follicular phase), gradually increasing until they reach their maximum concentration 2-4 days before ovulation (late follicular phase). There is an increased secretion of gonadotropin-releasing hormone, which then causes a sharp rise in LH. The increase in LH in the late follicular phase triggers ovulation, leading to the release of the ovum into the uterus.[3] The next stage is the luteal phase during which the resulting corpus luteum produces progesterone and small amounts of oestrogen. The peak of progesterone occurs in the middle luteal phase. If the ovum remains unfertilised, the corpus luteum will degenerate resulting in decreased levels of progesterone and oestrogen (late luteal phase). The lining of the uterus begins to peel indicating readiness for the start of the next cycle. [10,11]

These monthly changes in a woman's body caused by changes in hormone concentrations depending on the phase of the cycle affect various aspects of her life.

The Aim of The Study

Purpose of this study is to provide an overview of the menstrual cycle and to examine how hormonal fluctuations across its phases influence women's physical performance, well-being, and cognitive function. In particular, the study focuses on the effects of changes in estrogen and progesterone levels on exercise capacity, fatigue, thermoregulation, mood, and concentration. It also aims to highlight the importance of considering individual variability and cycle-related changes when planning training and recovery strategies.

Material and methods

This review is based on an analysis of literature collected from the PubMed, Google Scholar, and Scopus databases, as well as books and other scientific publications from the past 15 years. The sources were selected to provide a reliable overview of the topic. However, most of the information included in this review comes from studies published after 2019, in order to reflect current knowledge and recent research developments.

Results

Effects of hormones on the body and its processes

Sex hormones, such as oestradiol, can affect metabolism and other aspects of physiology at rest and during exercise, so it is important to consider how they affect exercise performance.

Physical performance is said to change during MC due to various mechanisms, such as altered muscle activation, substrate metabolism, thermoregulation and body composition. Concentrations of female sex hormones may be responsible for altered force production; this may affect muscle strength and power.

Estrogen is recognised as one of the major regulators of bioenergetics in women [5]. By acting directly on lipolytic enzymes, the hormone increases the availability of free fatty acids and promotes lipid oxidation in skeletal muscle [6], which is particularly intense during the late follicular and mid-luteal phases [7]. Thus, the increase in oestradiol during the luteal phase spares muscle glycogen, improving endurance performance [8]. One study found that exercise in the luteal phase resulted in 10% longer time to exhaustion (TTE) and was associated with greater glycogen replenishment. [9]

Estrogen mediates the effects of other hormones, such as cortisol, which promote lipolysis and glycogenesis at rest and reduce glycogenolysis during exercise [12,13]. Studies have observed that fat, carbohydrate and protein oxidation and glycogen storage differ according to the phase of the cycle, which has implications for performance and recovery. During intensive exercise in the follicular phase, fat oxidation, protein oxidation and glycogen storage decrease, while carbohydrate oxidation increases. In contrast, completely opposite processes occur during the luteal phase. [14,4] During lower intensity exercise, carbohydrate and lipid oxidation remained similar between the middle luteal phase and the late follicular phase [18,19].

The above studies suggest that a woman may achieve better performance during the luteal phase, especially in prolonged endurance exercise, due to better fat utilisation and glycogen sparing. The follicular phase may be more suitable for more intense workouts that use carbohydrates as the main energy source.

Oestrogen may also increase metabolism by affecting hormones that regulate it, such as thyroid hormones and growth hormone [16,17].

Female sex hormones also affect resting energy expenditure. During the luteal phase, increased fat oxidation associated with higher oestrogen concentrations translates into increased resting energy expenditure. In one study, this was confirmed to peak in the middle luteal phase, to be lower (-29 kcal/d) in the early follicular phase, and to be lowest after 6 days of oestrogen and progesterone suppression [20].This indicates that resting energy expenditure may vary according to the phase of the menstrual cycle and the concentration of female sex hormones. This is an important factor in the context of regeneration and proper nutrient intake.

Female sex hormones, through their effect on protein oxidation, are important for skeletal muscle growth and repair. During the luteal phase, when progesterone peaks, increased catabolic processes may occur [21, 22, 23]. Studies have shown that oxidation of phenylalanine, lysine and leucine is greater during this phase

[24, 25]. suggesting that oxidative removal of amino acids increases with increasing progesterone levels [4]. In contrast, increased oestrogen levels, which are associated with increased protein synthesis in combination with appropriate exercise, may improve muscle performance [15].

Body composition and weight

The change in performance can also be caused by transient fluctuations in body composition and weight during different phases of the cycle. Studies that dealt with body composition in female athletes during different phases of the menstrual cycle showed some contradictions. Some suggested that body weight and total body water did not change during the cycle [27]. Other studies, however, showed that there was a change in body weight as well as body water values depending on the phase of the cycle the woman was in. Increased progesterone production during the luteal phase was accompanied by an increase in body weight during this period. This hormone is responsible for lowering insulin concentrations in the body, which can translate into increased appetite and therefore weight fluctuations [28]. Fluid retention, on the other hand, is related to the action of aldosterone, whose levels increase during the luteal phase. An increase in body weight entails a decrease in aerobic endurance, which can affect poorer performance during sport. [29,30].

Temperature

Body temperature levels are also a factor that can affect performance.

Hormonal activity across the menstrual cycle exerts measurable effects on thermoregulation. Progesterone demonstrates thermogenic properties, contributing to an increase in basal body temperature during the luteal phase. In contrast, estrogen facilitates heat dissipation through vasodilation, thereby lowering the thermoregulatory threshold. During the luteal phase of the cycle, when progesterone levels are high, a woman's body temperature rises by 0.3°C to 0.7°C compared to the follicular phase. In the follicular phase, when oestrogen predominates, body temperature is lower [26].

The mechanism of action of progesterone involves a direct effect on the hypothalamus, the main thermoregulatory centre in the brain. Progesterone inhibits heat-sensitive neurons and stimulates cold-sensitive neurons, thereby increasing the body's thermal threshold. There are also reports that progesterone can increase heat production by affecting the mitochondria. Progesterone can directly act on progesterone receptors in the mitochondrial membrane and indirectly stimulate mitochondrial biogenesis, which increases mitochondrial number and activity[26,39] Estrogen, in turn, stimulates heat-sensitive neurons in the hypothalamus, which should theoretically lower body temperature. Estrogen may also affect the cardiovascular system, which indirectly influences thermoregulation. It promotes vasodilation, which increases blood flow and facilitates heat loss [40].

Furthermore, elevated temperature during the luteal phase may increase muscle contractility and force production, which may be beneficial for short-term, intense exercise [31]. At the same time, higher body temperature increases cardiovascular stress, especially during prolonged exercise [41].

Progesterone and oestrogen have complex effects on thermoregulation in women, acting at different levels, which may translate into female performance. The mechanisms of this action are not yet fully understood and require further research.

Strength

Muscle power and strength and affect the performance of the body. They provide sufficient energy to increase adaptability and resistance to fatigue. This translates into increased body performance and reduced risk of potential injury. [32,33] Sex-related differences in physical performance – such as strength, power, and speed – are largely determined by anatomical and physiological factors, including the influence of sex hormones. These distinctions become apparent during puberty, when testosterone levels in boys increase several times compared to girls. Muscle mass differs significantly between the two sexes. The number of skeletal muscles is smaller in women, while they have a higher proportional area of type I muscle fibres. This gives an advantage in fatigue resistance compared to men. [34, 35] Skeletal muscle is characterised by lower resistance to anabolic hormones in women compared to testosterone. Higher testosterone concentrations improve neuronal activation and muscle contractility. Study found a peak in the concentration of this hormone during ovulation, which could be associated with variable strength depending on the phase of the menstrual cycle [36, 42].

The central nervous system initiates muscle contractions and the contractile apparatus of the skeletal muscle pathway generates force and movement. The ability to cross the blood-brain barrier enables oestrogen and progesterone to influence CNS activation. Studies have shown that this was highest when oestrogen levels were highest (3-5 days before ovulation). High progesterone levels, on the other hand, resulted in decreased activation. [42] Estrogen and its neurostimulatory effects influence greater force production during the follicular phase while the inhibitory effect of progesterone on cortical excitability is associated with lower force during the luteal phase. [37] The rate of force production may also vary according to the phase of the menstrual cycle. In a study with women, the initial rate of activation of the medial vastus muscle and the medial vastus oblique muscle was compared. The results showed that in the follicular phase, the initial firing rate of the motor unit was slower than in the luteal phase. [38].

During the follicular phase (approximately 3-5 days before ovulation), women may notice better performance in exercises that require greater force production, such as strength training. This may be a period when it is worthwhile to increase the intensity of strength training, as the body is more likely to generate power.Conversely, during the luteal phase, when progesterone levels are high, women may notice reduced power and performance. During this period, it is worth considering reducing the intensity of workouts or adapting them to more endurance exercises that do not require as much maximum power. It is also worth extending recovery time during this phase, as the inhibitory effect of progesterone on the CNS can affect slower recovery of muscle strength.

Hormonal fluctuations affect performance and repair processes in skeletal muscle, thanks to oestrogen receptors located in muscle, tendons and mitochondria. Studies evaluating the relationship of muscle strength to the phase of the menstrual cycle have shown inconclusive differences in muscle strength, contractility and power. Some of the studies indicated that there were no differences in force production depending on the phase of the menstrual cycle although there were also contradictory findings.

The aim of the study by Blagrove and colleagues was to analyse the effect of menstrual cycle phase on strength parameters in women with a natural cycle. The meta-analysis included 21 articles and 232 participants, comparing strength outcomes across three phases: early follicular phase (EFP), ovulatory phase and mid-luteal phase (MLP). The authors used random-effects meta-analyses and found that differences in maximal contraction force, peak isokinetic torque and explosive force were minimal (Hedges $g < 0.2$). The results suggest that the phase of the menstrual cycle does not have a significant effect on strength-related outcomes [46].

A network meta-analysis was conducted by McNulty and colleagues to examine the effect of menstrual cycle phase on strength and endurance exercise performance. The analysis included 73 studies with a total of 954 participants and included 220 outcome measures across six phases of the cycle: early follicular phase (EFP), late follicular phase (LFP), ovulation, early luteal phase (ELP), mid-luteal phase (MLP) and late luteal phase (LLP). Results from all comparisons indicated trivial effect sizes (ES = 0.01-0.14), with the largest difference between EFP and LFP. The authors suggested that exercise performance may be minimally reduced during EFP, but due to the small effect size, high variability between studies, they emphasised that general recommendations cannot be made. [47]

In another study, researchers analysed the effect of the menstrual cycle on exercise-induced muscle damage (EIMD). The analysis included 19 studies with a total of 226 participants. The authors used standardised mean differences to assess muscle soreness and strength from the beginning to the end of exercise in three phases of the cycle: early follicular phase (EFP), late follicular phase (LFP) and mid-luteal phase (MLP). The greatest changes in delayed muscle soreness (DOMS) and loss of strength were observed in EFP and the least in MLP. The authors suggest that lower training loads or longer recovery periods are worth considering in EFP, whereas in MLP they recommend increasing strength training loads. [48]. As women may experience more muscle soreness (DOMS) in the early follicular phase, it is worth considering longer recovery times and lighter training loads in this phase of the cycle. On the other hand, during the luteal phase (especially in the MLP), women may tolerate more intense strength training better and their recovery is faster.

Various studies produce conflicting results regarding the impact of the menstrual cycle on strength and power. Some studies show no differences, while others show minimal changes depending on the phase of the cycle. It follows that the variability in results may be related to individual differences in women's bodies and the methodology of individual studies (e.g. differences in exercise type, intensity or assessment parameters).

Injuries

Fluctuations in oestrogen and progesterone levels during the cycle, which can affect muscle strength, joint stability and tissue repair processes, are a factor in the risk of injury in female athletes.

Several studies suggest that injury susceptibility may be elevated around ovulation, coinciding with peak estrogen concentrations. This hormonal profile is associated with reduced collagen stability and altered neuromuscular control, potentially predisposing athletes to soft tissue injuries [43].

Oestrogen can affect reduced collagen production in tendons and ligaments, which can lead to their weakness and increased risk of injury. Its high levels may also increase soft tissue elasticity, which on the one hand may improve range of motion, but on the other may increase the risk of muscle strains and strains. [44].

Although research on the relationship between the menstrual cycle and injury risk is inconclusive, many studies suggest that hormonal fluctuations have a significant impact on women's susceptibility to injury. During the ovulatory phase, when oestrogen levels are high, injury risk appears to be elevated.

Recovery

Recovery is an essential element for maintaining exercise performance and reducing the risk of injury. It involves maintaining a balance between effort and rest. Higher levels of fatigue translate into poorer exercise adaptation and recovery. Research shows that men's skeletal muscles are more susceptible to fatigue compared to women's muscles. The female gender showed smaller decreases in ATP concentrations during intense exercise [52] and experienced less contractile impairment of the knee extensors [50,51]. This would support the notion that women require a shorter recovery period and recover more quickly after intense exercise. More recent work by Hackney, Kallamen and Aggon noted elevated IL-6 (an inflammatory marker used to assess recovery) values during the mid-follicular phase at rest, immediately after exercise and 24 hours after exercise when oestrogen levels peak. [49] Elevated estrogen levels, by increasing nitric oxide concentration and decreasing the synthesis of vasoconstricting agents, dilate blood vessels, improving the transport of oxygen and nutrients in the muscle. Improved blood flow to exercising muscles reduces fatigue and has a positive effect on recovery processes [52,53]. It also leads to an increased blood lactate threshold by transporting metabolic by-products out of skeletal muscle[54]. However, these mechanisms and the variability of lactate concentration depending on the phase of the menstrual cycle are not yet fully understood [56,57]. As does progesterone, which has been shown to have antioxidant properties by promoting the expression of antioxidant enzymes. In contrast, a recent meta-analysis that looked at the effects of the phases of the menstrual cycle in women on peripheral vascular function presented some 30 studies presenting evidence that endothelial function increases during the luteal phase [55]. In contrast, a recent meta-analysis that looked at the effects of the phases of the menstrual cycle in women on peripheral vascular function presented some 30 studies presenting evidence that endothelial function increases during the luteal phase [45].

Women may benefit from differences in regeneration depending on the phase of the menstrual cycle. The follicular phase, in which oestrogen is at higher levels, promotes better blood flow, which may support faster recovery after exercise. It is therefore advisable to adapt the intensity and type of exercise to this phase of the cycle. Estrogen also supports muscle recovery, reduces inflammation and improves oxygen and nutrient transport, which can translate into better training performance and faster recovery after intense exercise.

Thanks to natural hormonal mechanisms, women may have an advantage in terms of recovery and performance, especially during phases of the cycle when oestrogen levels are higher. Taking advantage of these cyclical changes in training and rest planning can lead to better sports performance and a lower risk of injury.

Conclusions

Adequate performance and recovery are essential elements for optimal training and satisfactory performance in athletes. Assessing the role of the menstrual cycle and the impact of fluctuations in female sex hormones during the month is an essential element in understanding the performance of women athletes.

A large percentage of active women report that their performance is dependent on the phase of the menstrual cycle they are currently in. In contrast, research on objective measures of performance during MC in eumenorrheic athletes does not provide a definitive indication of how performance may change during MC. The variable results in published studies are likely the result of inconsistent methodological practices.

In those that did show an effect, it could be inferred that strength and aerobic performance were at reduced levels during the luteal phase and it was during this phase that athletes reported the greatest decline in performance. [I have removed 62 flocks]. It can also be concluded that endurance performance is probably best during the early MC phase and anaerobic and strength performance during the ovulatory phase. Exercise-induced fatigue appeared to be greater in the luteal or follicular phase.

There are still many questions and uncertainties related to the impact of the menstrual cycle on athletes. Repeating measurements over multiple menstrual cycles will increase the chance of obtaining reliable results. Furthermore, the reporting of within-person data will increase transparency in sports research. In the future, confounding factors such as accurate serum ovarian hormone concentrations, the presence of ovulatory or non-ovulatory cycles, training and nutritional status should be taken into account. There is much scope for research into the effects of regular hormonal fluctuations, taking into account the task being performed, the environment and the limb involved.

Further research is needed to understand the impact of the menstrual cycle on performance in female athletes. This would provide a basis for developing effective training plans to maximise performance and maintain health.

Conflicts of Interest: The authors declare no conflicts of interest.

REFERENCES

1. ACOG Committee Opinion No. 651: Menstruation in girls and adolescents: Using the menstrual cycle as a vital sign. (2015). *Obstetrics & Gynecology, 126*(6), e143–e146. https://doi.org/10.1097/AOG.0000000000001215
2. Coast, E., Lattof, S. R., & Strong, J. (2019). Puberty and menstruation knowledge among young adolescents in low- and middle-income countries: A scoping review. *International Journal of Public Health, 64*(2), 293–304. https://doi.org/10.1007/s00038-019-01209-0
3. Pan, B., & Li, J. (2019). The art of oocyte meiotic arrest regulation. *Reproductive Biology and Endocrinology, 17*, 8. https://doi.org/10.1186/s12958-018-0445-8
4. Oosthuyse, T., & Bosch, A. N. (2010). The effect of the menstrual cycle on exercise metabolism. *Sports Medicine, 40*, 207–227. https://doi.org/10.2165/11317090-000000000-00000
5. Van Pelt, R. E., Gavin, K. M., & Kohrt, W. M. (2015). Regulation of body composition and bioenergetics by estrogens. *Endocrinology and Metabolism Clinics of North America, 44*, 663–676. https://doi.org/10.1016/j.ecl.2015.05.011
6. Oosthuyse, T., & Bosch, A. N. (2012). Oestrogen's regulation of fat metabolism during exercise and gender specific effects. *Current Opinion in Pharmacology, 12*, 363–371. https://doi.org/10.1016/j.coph.2012.02.008
7. Oosthuyse, T., Strauss, J. A., & Hackney, A. C. (2023). Understanding the female athlete: Molecular mechanisms underpinning menstrual phase differences in exercise metabolism. *European Journal of Applied Physiology, 123*, 423–450. https://doi.org/10.1007/s00421-022-05090-3
8. Oosthuyse, T., & Bosch, A. N. (2010). The effect of the menstrual cycle on exercise metabolism: Implications for exercise performance in eumenorrhoeic women. *Sports Medicine, 40*, 207–227. https://doi.org/10.2165/11317090-000000000-00000
9. Nicklas, B. J., Hackney, A. C., & Sharp, R. L. (1989). The menstrual cycle and exercise: Performance, muscle glycogen, and substrate responses. *International Journal of Sports Medicine, 10*(4), 264–269. https://doi.org/10.1055/s-2007-1024913
10. Patricio, B.-P., & Sergio, B.-G. (2019). Normal menstrual cycle. In *Menstrual cycle*. https://doi.org/10.5772/intechopen.79876
11. Holesh, J., Bass, A., & Lord, M. (2020). Physiology, ovulation. In *StatPearls*. StatPearls.
12. Oosthuyse, T., & Bosch, A. N. (2012). Oestrogen's regulation of fat metabolism during exercise and gender specific effects. *Current Opinion in Pharmacology, 12*, 363–371. https://doi.org/10.1016/j.coph.2012.02.008
13. Hackney, A. C. (2021). Menstrual cycle hormonal changes and energy substrate metabolism in exercising women: A perspective. *International Journal of Environmental Research and Public Health, 18*, 10024. https://doi.org/10.3390/ijerph181910024
14. Wohlgemuth, K. J., Arieta, L. R., Brewer, G. J., Hoselton, A. L., Gould, L. M., & Smith-Ryan, A. E. (2021). Sex differences and considerations for female specific nutritional strategies: A narrative review. *Journal of the International Society of Sports Nutrition, 18*, 27. https://doi.org/10.1186/s12970-021-00422-8
15. Myllyaho, M. M., Ihalainen, J. K., Hackney, A. C., Valtonen, M., Nummela, A., Vaara, E., Häkkinen, K., Kyröläinen, H., & Taipale, R. S. (2021). Hormonal contraceptive use does not affect strength, endurance, or body composition adaptations to combined strength and endurance training in women. *Journal of Strength and Conditioning Research, 35*, 449–457. https://doi.org/10.1519/JSC.0000000000002713
16. Giersch, G. E. W., Charkoudian, N., Stearns, R. L., et al. (2020). Fluid balance and hydration considerations for women: Review and future directions. *Sports Medicine, 50*, 253–261. https://doi.org/10.1007/s40279-019-01206-6
17. Oosthuyse, T., & Bosch, A. N. (2010). The effect of the menstrual cycle on exercise metabolism. *Sports Medicine, 40*, 207–227. https://doi.org/10.2165/11317090-000000000-00000
18. Hackney, A. C., McCracken-Compton, M. A., & Ainsworth, B. (1994). Substrate responses to submaximal exercise in the midfollicular and midluteal phases of the menstrual cycle. *International Journal of Sport Nutrition, 4*, 299–308. https://doi.org/10.1123/ijsn.4.3.299
19. Vaiksaar, S., Jürimäe, J., Mäestu, J., et al. (2011). No effect of menstrual cycle phase on fuel oxidation during exercise in rowers. *European Journal of Applied Physiology, 111*, 1027–1034. https://doi.org/10.1007/s00421-010-1730-1

20. Day, D. S., Gozansky, W. S., Van Pelt, R. E., Schwartz, R. S., & Kohrt, W. M. (2005). Sex hormone suppression reduces resting energy expenditure and β-adrenergic support of resting energy expenditure. *Journal of Clinical Endocrinology & Metabolism, 90*, 3312–3317. https://doi.org/10.1210/jc.2004-1344
21. Draper, C. F., Duisters, K., Weger, B., Chakrabarti, A., Harms, A. C., Brennan, L., Hankemeier, T., Goulet, L., Konz, T., Martin, F. P., et al. (2018). Menstrual cycle rhythmicity: Metabolic patterns in healthy women. *Scientific Reports, 8*, 14568. https://doi.org/10.1038/s41598-018-32647-0
22. Kriengsinyos, W., Wykes, L. J., Goonewardene, L. A., Ball, R. O., & Pencharz, P. B. (2004). Phase of menstrual cycle affects lysine requirement in healthy women. *American Journal of Physiology-Endocrinology and Metabolism, 287*, E489–E496. https://doi.org/10.1152/ajpendo.00262.2003
23. Hamadeh, M. J., Devries, M. C., & Tarnopolsky, M. A. (2005). Estrogen supplementation reduces whole body leucine and carbohydrate oxidation and increases lipid oxidation in men during endurance exercise. *Journal of Clinical Endocrinology & Metabolism, 90*, 3592–3599. https://doi.org/10.1210/jc.2004-1743
24. Hansen, M., Langberg, H., Holm, L., Miller, B. F., Petersen, S. G., Doessing, S., Skovgaard, D., Trappe, T., & Kjaer, M. (2011). Effect of administration of oral contraceptives on the synthesis and breakdown of myofibrillar proteins in young women: Effect of OC on muscle protein turnover. *Scandinavian Journal of Medicine & Science in Sports, 21*, 62–72. https://doi.org/10.1111/j.1600-0838.2009.01002.x
25. Lariviere, F., Moussalli, R., & Garrel, D. R. (1994). Increased leucine flux and leucine oxidation during the luteal phase of the menstrual cycle in women. *American Journal of Physiology-Endocrinology and Metabolism, 267*, E422–E428. https://doi.org/10.1152/ajpendo.1994.267.3.E422
26. Baker, F. C., Siboza, F., & Fuller, A. (2020). Temperature regulation in women: Effects of the menstrual cycle. *Temperature, 7*(3), 226–262. https://doi.org/10.1080/23328940.2020.1735927
27. Rael, B., Romero-Parra, N., Alfaro-Magallanes, V. M., Barba-Moreno, L., Cupeiro, R., De Jonge, X. J., & Peinado, A. B. (2020). Body composition over the menstrual and oral contraceptive cycle in trained females. *International Journal of Sports Physiology and Performance*, 1–7. https://doi.org/10.1123/ijspp.2020-0038
28. Akturk, M., Törüner, F., Aslan, S., Altinova, A. E., Cakir, N., Elbeg, S., & Arslan, M. (2013). Circulating insulin and leptin in women with and without premenstrual disphoric disorder in the menstrual cycle. *Gynecological Endocrinology, 29*, 465–469. https://doi.org/10.3109/09513590.2013.769512
29. Maciejczyk, M., Wiecek, M., Szymura, J., Cempla, J., Wiecha, S., Szygula, Z., & Brown, L. E. (2014). Effect of body composition on respiratory compensation point during an incremental test. *Journal of Strength and Conditioning Research, 28*, 2071–2077. https://doi.org/10.1519/JSC.0000000000000347
30. Maciejczyk, M., Więcek, M., Szymura, J., Szyguła, Z., Wiecha, S., & Cempla, J. (2014). The influence of increased body fat or lean body mass on aerobic performance. *PLoS ONE, 9*, e95797. https://doi.org/10.1371/journal.pone.0095797
31. Girard, O., Brocherie, F., & Bishop, D. J. (2015). Sprint performance under heat stress: A review. *Scandinavian Journal of Medicine & Science in Sports, 25*, 79–89. https://doi.org/10.1111/sms.12437
32. Dave, H., Shook, M., & Varacallo, M. (2023). Anatomy, skeletal muscle. In *StatPearls*. StatPearls Publishing.
33. Grgic, J., Lazinica, B., Schoenfeld, B. J., & Pedisic, Z. (2020). Test-retest reliability of the one-repetition maximum (1RM) strength assessment: A systematic review. *Sports Medicine - Open, 6*, 31. https://doi.org/10.1186/s40798-020-00260-z
34. Ansdell, P., Thomas, K., Hicks, K. M., Hunter, S. K., Howatson, G., & Goodall, S. (2020). Physiological sex differences affect the integrative response to exercise: Acute and chronic implications. *Experimental Physiology, 105*, 2007–2021. https://doi.org/10.1113/EP088548
35. Hunter, S. K., Angadi, S. S., Bhargava, A., Harper, J., Hirschberg, A. L., Levine, B. D., Moreau, K. L., Nokoff, N. J., Stachenfeld, N. S., & Bermon, S. (2023). The biological basis of sex differences in athletic performance: Consensus statement for the American College of Sports Medicine. *Translational Journal of the American College of Sports Medicine, 8*, 1–33. https://doi.org/10.1249/TJX.0000000000000236
36. Rickenlund, A., Carlström, K., Ekblom, B., Brismar, T. B., von Schoultz, B., & Hirschberg, A. L. (2004). Effects of oral contraceptives on body composition and physical performance in female athletes. *Journal of Clinical Endocrinology & Metabolism, 89*, 4364–4370. https://doi.org/10.1210/jc.2003-031334
37. Pallavi, L. C. (2017). Assessment of musculoskeletal strength and levels of fatigue during different phases of menstrual cycle in young adults. *Journal of Clinical and Diagnostic Research, 11*, CC11–CC13. https://doi.org/10.7860/JCDR/2017/24316.9408
38. Tenan, M. S., Peng, Y.-L., Hackney, A. C., & Griffin, L. (2013). Menstrual cycle mediates vastus medialis and vastus medialis oblique muscle activity. *Medicine & Science in Sports & Exercise, 45*, 2151–2157. https://doi.org/10.1249/MSS.0b013e318299a69d
39. Rodríguez-Cuenca, S., Monjo, M., Gianotti, M., et al. (2007). Expression of mitochondrial biogenesis-signaling factors in brown adipocytes is influenced specifically by 17β-estradiol, testosterone, and progesterone. *American Journal of Physiology-Endocrinology and Metabolism, 292*, E340–E346. https://doi.org/10.1152/ajpendo.00175.2006

40. Rance, N. E., Dacks, P. A., Mittelman-Smith, M. A., et al. (2013). Modulation of body temperature and LH secretion by hypothalamic KNDy (kisspeptin, neurokinin B and dynorphin) neurons: A novel hypothesis on the mechanism of hot flushes. *Frontiers in Neuroendocrinology, 34*, 211–227. https://doi.org/10.1016/j.yfrne.2013.07.003
41. Carmichael, M. A., Thomson, R. L., Moran, L. J., & Wycherley, T. P. (2021). The impact of menstrual cycle phase on athletes' performance: A narrative review. *International Journal of Environmental Research and Public Health, 18*(4), 1667. https://doi.org/10.3390/ijerph18041667
42. Cabre, H. E., Gould, L. M., Redman, L. M., & Smith-Ryan, A. E. (2024). Effects of the menstrual cycle and hormonal contraceptive use on metabolic outcomes, strength performance, and recovery: A narrative review. *Metabolites, 14*(7), 347. https://doi.org/10.3390/metabo14070347
43. Shagawa, M., Maruyama, S., Sekine, C., Yokota, H., Hirabayashi, R., Hirata, A., Yokoyama, M., & Edama, M. (2021). Comparison of anterior knee laxity, stiffness, genu recurvatum, and general joint laxity in the late follicular phase and the ovulatory phase of the menstrual cycle. *BMC Musculoskeletal Disorders, 22*, 886. https://doi.org/10.1186/s12891-021-04767-8
44. Martínez-Fortuny, N., Alonso-Calvete, A., Da Cuña-Carrera, I., & Abalo-Núñez, R. (2023). Menstrual cycle and sport injuries: A systematic review. *International Journal of Environmental Research and Public Health, 20*(4), 3264. https://doi.org/10.3390/ijerph20043264
45. Williams, J. S., Dunford, E. C., & MacDonald, M. J. (2020). Impact of the menstrual cycle on peripheral vascular function in premenopausal women: Systematic review and meta-analysis. *American Journal of Physiology-Heart and Circulatory Physiology, 319*, H1327–H1337. https://doi.org/10.1152/ajpheart.00341.2020
46. Blagrove, R. C., Bruinvels, G., & Pedlar, C. R. (2020). Zmiany w pomiarach siły w trakcie cyklu menstruacyjnego u kobiet z eumenorreią: Przegląd systematyczny i metaanaliza. *Journal of Science and Medicine in Sport, 23*(12), 1220–1227. https://doi.org/10.1016/j.jsams.2020.04.022
47. McNulty, K. L., Elliott-Sale, K. J., Dolan, E., Swinton, P. A., Ansdell, P., Goodall, S., et al. (2020). Wpływ fazy cyklu menstruacyjnego na wydajność ćwiczeń u kobiet z eumenorreią: Przegląd systematyczny i metaanaliza. *Sports Medicine, 50*(10), 1813–1827. https://doi.org/10.1007/s40279-020-01319-3
48. Romero-Parra, N., Cupeiro, R., Alfaro-Magallanes, V. M., Rael, B., Rubio-Arias, J. Á., Peinado, A. B., et al. (2021). Uszkodzenie mięśni wywołane wysiłkiem fizycznym w trakcie cyklu menstruacyjnego: Przegląd systematyczny i metaanaliza. *Journal of Strength and Conditioning Research, 35*(2), 549–561. https://doi.org/10.1519/JSC.0000000000003878
49. Hackney, A. C., Kallman, A. L., & Ağgön, E. (2019). Female sex hormones and the recovery from exercise: Menstrual cycle phase affects responses. *Biomedical Human Kinetics, 11*, 87–89. https://doi.org/10.2478/bhk-2019-0011
50. Ansdell, P., Brownstein, C. G., Škarabot, J., Hicks, K. M., Howatson, G., Thomas, K., Hunter, S. K., & Goodall, S. (2019). Sex differences in fatigability and recovery relative to the intensity–duration relationship. *The Journal of Physiology, 597*, 5577–5595. https://doi.org/10.1113/JP278699
51. Ansdell, P., Škarabot, J., Atkinson, E., Corden, S., Tygart, A., Hicks, K. M., Thomas, K., Hunter, S. K., Howatson, G., & Goodall, S. (2020). Sex differences in fatigability following exercise normalised to the power–duration relationship. *The Journal of Physiology, 598*, 5717–5737. https://doi.org/10.1113/JP280031
52. Hunter, S. K. (2016). Sex differences in fatigability of dynamic contractions: Sex differences in skeletal muscle fatigue. *Experimental Physiology, 101*, 250–255. https://doi.org/10.1113/EP085370
53. Beltrame, T., Villar, R., & Hughson, R. L. (2017). Sex differences in the oxygen delivery, extraction, and uptake during moderate-walking exercise transition. *Applied Physiology, Nutrition, and Metabolism, 42*, 994–1000. https://doi.org/10.1139/apnm-2017-0097
54. Korthuis, R. J. (2011). *Skeltal muscle circulation*. Morgan & Claypool Life Sciences.
55. Enns, D. L., & Tiidus, P. M. (2010). The influence of estrogen on skeletal muscle: Sex matters. *Sports Medicine, 40*, 41–58. https://doi.org/10.2165/11319760-000000000-00000
56. Lara, B., Gutiérrez Hellín, J., Ruíz-Moreno, C., Romero-Moraleda, B., & Del Coso, J. (2020). Acute caffeine intake increases performance in the 15-s Wingate test during the menstrual cycle. *British Journal of Clinical Pharmacology, 86*, 745–752. https://doi.org/10.1111/bcp.14175
57. Štefanovský, M., Péterová, A., Vanderka, M., & Lengvarský, L. (2016). Influence of selected phases of the menstrual cycle on performance in special judo fitness test and Wingate test. *Acta Gymnica, 46*, 136–142. https://doi.org/10.5507/ag.2016.015