




A Narrative Review - Exploring the Influence of the Menstrual Cycle on Badminton Performance and ACL injury occurrence

Revisión narrativa – Exploración de la influencia del ciclo menstrual en el rendimiento en el bádminton y la aparición de lesiones del LCA

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Abstract

To date, there exists a notable gap in research specifically exploring the influence of the menstrual cycle on female badminton athletes' performance during trainings and competitions. Existing scientific literature on the relationship between the menstrual cycle and sports performance, found through platforms like PubMed, Google Scholar among others, primarily draws insights from studies conducted in other sports such as handball, rugby, football, volleyball or athletics. The literature review for this study included fifteen articles, two of which were systematic reviews. The selected studies focused on healthy eumenorrheic female athletes, aged 17 to 30 years, who were not using contraceptive pills and were competed to at least in a national level. However, due to the natural diversity among women, and the multifactorial environment that influences the human being, reassuring that a certain type of training must be followed on a determined menstrual cycle's phase or that a certain injury does occur primarily in a certain period of the cycle, remain unclear. Nevertheless, what is evident is that numerous hormonal and physiological changes occur through the cycle, and that these changes might have an impact on the female athlete's performance. Exploring this area through dedicated research and understanding these nuances can facilitate tailored training approaches to enhance performance and mitigate any associated challenges. Hence, normalizing discussions around the menstrual cycle and gaining familiarity with it, will play a role not only on the athlete performance but also on their well-being.

Keywords: *badminton, menstrual cycle, awareness, ACL, strength training.*

Resumen

Hasta la fecha, existe un vacío notable en la investigación que explora específicamente la influencia del ciclo menstrual en el rendimiento de las atletas de bádminton durante los entrenamientos y las competiciones. La literatura científica existente sobre la relación entre el ciclo menstrual y el rendimiento deportivo encontrada a través de plataformas como PubMed, Google Scholar, entre otras, se nutre principalmente de estudios realizados en otros deportes como balonmano, rugby, fútbol, voleibol o atletismo. La revisión bibliográfica para este estudio incluyó quince artículos, dos de los cuales son revisiones sistemáticas. Los estudios seleccionados se centraron en atletas mujeres eumenorreicas sanas de entre 17 y 30 años que no utilizaban pastillas anticonceptivas y que competían al menos a nivel nacional. Sin embargo, debido a la diversidad natural entre las mujeres y al entorno multifactorial que influye en el ser humano, asegurar que un determinado tipo de entrenamiento debe seguirse en una determinada fase del ciclo menstrual o que una determinada lesión se produce principalmente en un determinado periodo del ciclo, sigue siendo incierto. No obstante, lo que es evidente es que a lo largo del ciclo se producen numerosos cambios hormonales y fisiológicos que pueden repercutir en el rendimiento de las atletas. Explorar este ámbito mediante una investigación específica y comprender estos matices

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puede facilitar enfoques de entrenamiento adaptados para mejorar el rendimiento y mitigar cualquier dificultad asociada. Por lo tanto, normalizar los debates en torno al ciclo menstrual y familiarizarse con él no solo influirá en el rendimiento de las deportistas sino también en su bienestar.

Palabras clave: *bádminton, ciclo menstrual, concienciación, LCA, entrenamiento de fuerza.*

INTRODUCTION

Despite increasing research into the menstrual cycle (MC) and female performance over the years, it remains unclear whether there is an optimal phase in the cycle for performance (Meignié et al., 2019; Julian et al., 2017). However, it is evident that women experience continuous variations in serum concentrations of several female sex steroid hormones throughout the cycle (Anckaert et al., 2021). These fluctuations in the MC, along with associated physical and psychological symptoms such as dysmenorrhea, flooding, reduced energy levels, worry, distraction, fluctuating emotions, and reduced motivation, can often have a negative impact on daily life and activities, including work, school, or physical performance (Findlay et al., 2020).

In addition, badminton stands out as one of the sports with a heightened risk of ACL injuries, particularly among female athletes (Hu et al., 2023). While literature exists on common movements predisposing athletes to ACL injuries in badminton, the potential correlation with the menstrual cycle phase remains largely unexplored. Understanding the MC's functioning and extrapolating it into the characteristics and physiology of badminton, could prompt discussions and potentially introduce new opportunities to optimize athletes' performance and reduce injury risk.

Menstrual Cycle functioning

Throughout the menstrual cycle, all women experience consistent fluctuations in the levels of various female hormones in their bloodstream. These fluctuations, primarily involving estrogens, progesterone, follicle stimulating hormone (FSH), and luteinizing hormone (LH), play a crucial role in regulating the ovulatory cycle's patterns. They lead to two principal phases: the follicular phase and the luteal phase, with a brief ovulation period (and potentially considered as a third phase) between them. The follicular phase typically comprises the early follicular phase (EFP), characterized by low estrogens and progesterone levels and where the menses take place, and the late follicular phase (LFP), marked by a peak in estrogens alongside low progesterone levels, culminating in a surge of luteinizing hormone just before the ovulation. The luteal phase commences after luteinizing hormone levels return to baseline and is defined by elevated levels of both estrogens and progesterone (being the last one significantly higher). Peak concentrations of

these hormones usually occur during the mid-term of the luteal phase (MLP) (Romero-Moraleda et al., 2019) (figure 1). In the mentioned figure, the hormonal fluctuations of estrogens and progesterone during the menstrual cycle and the different phases that encompasses it has been displayed:

Although the primary function of estrogens and progesterone is to support reproduction, research has demonstrated that the fluctuating concentrations of these hormones across the MC also exert diverse and complex effects on various physiological systems, including cardiovascular, respiratory, metabolic, and neuromuscular parameters. These hormonal variations can significantly impact exercise performance, with reductions observed during the early follicular phase of the MC compared to other phases (McNulty et al., 2020). Additionally, physical symptoms, mood disturbances, and decreased motivation to train have been reported during this phase as well (Brown et al., 2021). According to Findlay et al. (2020), in her research regarding how the menstrual cycle and menstruation affect sporting performance in elite female rugby players, the 93% of the athletes reported having menstrual cycle-related symptoms such as dysmenorrhoea, flooding, reduced energy levels, worry, distraction, fluctuating emotions or reduced motivation. Thirty-three per cent perceived heavy menstrual bleeding and 67% considered these symptoms clearly impaired their performances.

Studies show that estrogens induce anabolic, and muscle building processes in females, and its impact is not necessarily shown by increased muscle but instead, by enabling muscle fibers to generate greater force (Lowe et al., 2010). Additionally, estrogens have been shown to have antioxidant and membrane stabiliser properties, which might offer protection against exercise-induced muscle damage and reduce inflammatory responses (Mihm et al., 2011).

On the other hand, progesterone has the complete opposite effect. As such, progesterone has been associated with protein catabolism, possibly attenuating muscle strength (Oosthuysen and Bosch, 2010). Furthermore, it causes a slight increase in basal body temperature, which can be tracked as an indicator of ovulation. This factor might as well affect athletes' endurance and thermoregulation.

The decrease of both oestrogens and progesterone (see figure 1 from days 1-5) causes the endometrium to shed, resulting in the menstruation.

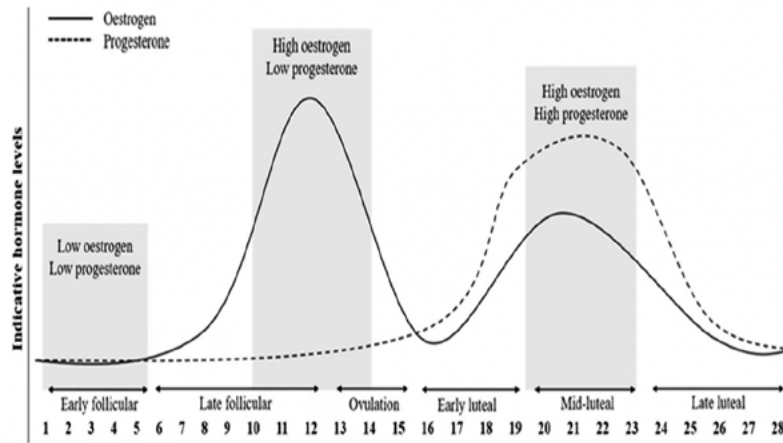


Figure 1. Schematic displaying the hormonal fluctuations across an idealized 28-day MC, with ovulation occurring on day 14 (adapted from Pitchers and Elliott-Sale and extracted from McNulty et al, 2020).

METHODS

The literature review for this study included fifteen articles, two of which were systematic reviews. The selected studies focused on healthy eumenorrhic female athletes, aged 17 to 30 years, who were not using contraceptive pills.

Due to the lack of research specifically related to the menstrual cycle and badminton, studies from other sports such as soccer, handball, volleyball, and rugby were reviewed. The findings from these sports were extrapolated to badminton to draw relevant conclusions.

The female athletes profiled in these studies were between 17 and 30 years old and competed at least at a national level. Additionally, three articles specifically related to badminton were included to better understand gender differences in neuromuscular control during the preparation phase of single-leg landing and the associated risk of ACL injury.

RESULTS AND DISCUSSIONS

Strength training & menstrual cycle in badminton

The purpose of this section is to enhance comprehension of the menstrual cycle in female athletes, with a specific focus on female badminton players, and provide with some guidance that could be taken into consideration in female badminton players' routines to optimize their strengthened conditioning.

There is a clear lack of evidence-based recommendations on individualizing strength training according to the menstrual cycle in female badminton athletes.

Nevertheless, it is well established that strength training is a crucial component of performance for badminton athletes, both male and female. It builds muscular strength and endurance, reducing the risk of injuries by stabilizing joints and supporting connective

tissues during explosive movements, quick changes in direction, and repetitive motions. Strength training also enhances muscle power and explosiveness, enabling badminton athletes to generate more force in strokes and movements such as smashing, jumping, or lunging. Improved speed and agility are essential for reacting quickly to opponents' shots and maintaining optimal positioning during rallies. Additionally, strength training improves muscular endurance, delaying fatigue onset and enabling sustained performance throughout matches and training sessions. It also contributes to factors such as balance and stability, muscle imbalance correction, and psychological benefits.

For female badminton athletes, optimizing strength training can add value to training and competition, not only for high-performance and elite players but also for younger categories such as junior players. Understanding the physiological changes in their bodies and how they manifest can help players and coaches optimize their training sessions.

While recent research remains unclear regarding whether one menstrual cycle phase offers better strength improvement than another (follicular phase vs. luteal phase), clear physiological patterns play a key role and should be taken into consideration when planning a female badminton player program.

Physiologically, estrogen levels rise during the late follicular and ovulatory phases and remain elevated in the mid-luteal phase. Estrogens induce anabolic and muscle-building processes in females, enabling muscle fibers to generate greater force (Lowe et al., 2010). Additionally, free testosterone levels increase in the late follicular phase, which may be related to increased muscle diameter (Sung et al., 2014). Furthermore, during the late follicular and ovulatory phases, estrogens concentration is not affected by the rise in progesterone concentration, unlike the mid-luteal phase where both hormones remain high, potentially impacting estrogen's anabolic effect negatively due to

the catabolic influence of progesterone (McNulty et al., 2020).

Considering these physiological responses, and taking into consideration how the catabolic effect of progesterone can notably influence the estrogens' role, it could be beneficial to emphasize strength training during the late follicular and ovulatory phases of the menstrual cycle where the estrogens are acting at their highest peak without being influenced. On the contrary, it would make sense to reduce it at the beginning of the follicular phase, just when menses occur and where there is a significant drop in oestrogen and progesterone levels, which could unleash to flooding, reduced energy levels, worry, distraction, fluctuating emotions, and reduced motivation (Findlay et al., 2020). In addition, during the late luteal phase and despite the estrogen's levels being still high, the effect of progesterone prevails, which might as well reduce the ultimate outcome. Nevertheless, it is important to always bear in mind that a female badminton athlete's performance is multifactorial, influenced not only by the menstrual cycle and its hormones, but also by factors such as sleep quality, personal life, nutrition, lifestyle, previous injuries, training loads, stress, among many other factors. Consequently, it is recommended to adopt a personalized approach based on each female badminton athlete's response to exercise performance across the menstrual cycle, as everyone can have a different response depending on the environment and circumstances that are being faced at a particular time.

Risk of ACL injury in female badminton players and menstrual cycle

The aim of this section is to explain the relationship between hormonal fluctuations in the MC and anterior cruciate ligament (ACL) injuries in badminton players. Additionally, it aims to identify the phase of the menstrual cycle during which women may be more susceptible to sustaining such injuries.

In general, women are estimated to be approximately five times more prone to ACL injuries than men when engaging in comparable levels of exercise. In badminton, one common scenario leading to such injuries is the execution of a single-leg landing task following a backcourt backhand side overhead stroke (Zang et al., 2023). According to Kaldau et al. (2024), data from the Danish National Patient Register, covering patients in Denmark from 2000 to 2018 with a diagnosis of ACL rupture who identified badminton as their primary sport, were analyzed for return to sport (RTS) and return to performance (RTP) after ACL injury. Out of these patients, 396 (63%) returned to playing badminton, but only 117 (19%) regained their pre-injury performance level. Additionally, both RTS and RTP rates were higher in male compared to female badminton players, highlighting the importance of continued investigation into this matter.

Several relevant factors contribute to the origin of ACL injuries, including musculoskeletal and neuromuscular differences. Zang et al. (2023) found that female athletes exhibit significantly lower absolute and normalized leg stiffness, as well as knee stiffness during landing, compared to male athletes. This suggests that female athletes may be more susceptible to non-contact ACL injuries during landing motion due to lower leg dynamic stability and higher knee hypermobility.

Another contributing factor is weak gluteal strength, which predisposes individuals to hip muscle fatigue and subsequent knee instability (Hu et al., 2023). Moreover, Anne Benjaminse et al. highlighted the significant effect of fatigue on ACL injury risk during exercise. This underscores the importance of addressing muscle fatigue, particularly in the gluteal muscles, to mitigate ACL injury risk in female badminton players. Injuries in badminton players, including ACL injuries, are influenced by a variety of factors such as biomechanical, anatomical, environmental, and hormonal aspects.

One hormonal factor that might as well impact the predisposition to ACL injury is the hormonal fluctuations during the menstrual cycle. Although the precise relationship between the menstrual cycle, fluctuation of female sex hormones, and subsequent injuries still remains to be clarified, there are correlations associated with physiological variations resulting from increased estradiol levels. These variations include joint and ligament laxity, reduced strength, and impaired neuromuscular control (Martinez-Fortuny et al., 2023; Khowailed et al., 2015), which are correlated with an increase of injury.

A systematic review of 408 athletes revealed an increased incidence of non-contact ACL injuries during the preovulatory (first half) phase of the menstrual cycle, occurring between the menses (1-5 days) and the ovulation (6-15 days).

The ovulation phase corresponds to the period of highest estradiol levels. However, this factor does not necessarily coincide with the peak risk of injury (Hewett et al., 2007).

In badminton, where injury risk is multifactorial and individual, it is imperative for players and coaches to recognize the physiological variations associated with the menstrual cycle that may affect their neuromuscular control and being able to identify them (in some of the cases), as well as communicate them. Awareness of these factors enables coaches to tailor physical preparation programs, on and off court, to mitigate the incidence of ACL injuries.

By acknowledging the unpredictable nature of badminton and being aware of the phases where the release of certain hormones such as relaxin and estradiol occurs, the coaches and athletes may find it beneficial, (as long as the athlete's time and schedule allow it) an approach that involves reducing the

unpredictability of on-court exercises, to minimize the risk of injury caused by increased joint and ligament laxity combined with impaired neuromuscular control together with a major focus on strength conditioning during the preovulatory phase, and most particularly during the late follicular phase when estrogen levels peak, could be beneficial too.

Emphasizing strength training during this time could be an optimal period to incorporate specialized exercises to reduce the ACL injury risk. Current research suggests that programs including isokinetic strength exercises for knee flexor and extensor muscles might help badminton players with movement control. Furthermore, strengthening the hip and gluteal muscles is crucial, as this can improve knee stability (Hu et al., 2023) and maintain dynamic valgus control (Pournasiri et al., 2023).

By implementing certain adaptations in the athlete's sessions, coaches could potentially mitigate ACL injury risks and optimize performance, recognizing the physiological nuances that might impact female athlete's well-being and performance.

CONCLUSION

The relationship between the menstrual cycle and sports performance, particularly in badminton, remains largely unexplored. While some findings in strength training and injury predisposition have provided valuable insights, they do not offer a comprehensive understanding of this complex interaction.

Both coaches and athletes often lack awareness in this area. Understanding the menstrual cycle extends beyond recognizing hormonal changes and physiological aspects; it involves comprehending the entire process, normalizing the associated symptoms, and acknowledging their impact on athletes throughout their careers.

Raising awareness about the menstrual cycle should begin early in player development, rather than being confined to elite levels. Initiating research on the menstrual cycle and badminton performance could reveal critical physiological patterns, equipping players and coaches with a solid foundation of knowledge that could eventually enhance performance and well-being.

Even in the absence of extensive research, coaches should strive to understand their female athletes' menstrual cycles better. Encouraging open discussions and utilizing questionnaires to gather data on cycle length, blood flow intensity, and symptoms (such as cramps, headaches, mood swings, and concentration issues) can provide valuable insights. Understanding how these factors affect athletes both physically and emotionally will enable more effective adaptation and support.

Additionally, tracking fatigue levels on a Borg scale can help coaches and players identify patterns

and make informed decisions when organizing and adapting training plans.

This proactive approach can significantly enhance player-coach communication, leading to better stress management and overall health.

By openly discussing menstrual health, athletes and coaches can identify optimal training times, anticipate and manage symptoms, and adjust workloads to prevent overtraining or injuries. This strategy not only reduces stress but also enhances performance monitoring. Additionally, it promotes a supportive and empathetic environment, encouraging athletes to prioritize their well-being and long-term career sustainability.

In the absence of menstrual cycle research and badminton, here are some potential key areas to consider as a starting point in this still unknown field:

- How changes in estrogen and progesterone levels during the menstrual cycle affect physical performance, endurance, muscle strength and recovery.
- Whether different phases of the menstrual cycle might affect reaction time, coordination, and precision in badminton-specific skills such as service, smash or footwork.
- Assess how mood swings, anxiety, and motivation levels fluctuate during the menstrual cycle and how these changes impact training intensity, competition performance, concentration and/or decision-making.
- Explore whether nutritional requirements change during the menstrual cycle and how athletes can optimize their diet to maintain peak performance and recovery.

By exploring these areas, valuable insights could be obtained that may help female badminton players optimize their training and performance throughout their menstrual cycle.

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