ORIGINAL ARTICLE

Study of menstrual cycle in training load variability in female basketball players

María de los Ángeles Arenas-Pareja. *Training and Sports Performance Optimization Group (GOERD). Faculty of Sports Sciences. University of Extremadura. Cáceres, Spain.*
Pablo López-Sierra ✉ **.** *Training and Sports Performance Optimization Group (GOERD). Faculty of Sports Sciences. University of Extremadura. Cáceres, Spain.*
Sergio J. Ibáñez. *Training and Sports Performance Optimization Group (GOERD). Faculty of Sports Sciences. University of Extremadura. Cáceres, Spain.*
Javier García-Rubio. *Training and Sports Performance Optimization Group (GOERD). Faculty of Sports Sciences. University of Extremadura. Cáceres, Spain.*

ABSTRACT

The menstrual cycle is a key factor influencing athletic performance. This study analysed its impact on the training load of female basketball players over a two-month period using a case series design with ten participants. Descriptive analysis, variation coefficients, mixed linear models, and regression techniques were applied to assess the relationship between menstrual phases and training variables. The results indicate that a significant portion of performance variability is linked to specific menstrual phases, with notable individual differences. Understanding these fluctuations is essential for optimizing training programs that align with athletes' physiological states. During phases of hormonal stability, such as the follicular phase, high-intensity training can be prioritized to maximize physical output, focusing on explosive movements, accelerations, and decelerations. Conversely, during the luteal or menstrual phase, when hormonal fluctuations may reduce fatigue tolerance, training should emphasize moderate-intensity or technical sessions to support recovery while maintaining performance. Incorporating menstrual cycle-aware training adaptations can improve athletic performance, reduce injury risk, and enhance overall well-being, underscoring the need for a more individualized approach to female athlete conditioning.

Keywords: Sport medicine, Women, Workload, Athletic performance.

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✉ **Corresponding author.** *Laboratorio GOERD (320), Facultad de Ciencias del Deporte, Universidad de Extremadura, 10003 Cáceres, España.*
E-mail: pablols@unex.es
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INTRODUCTION

Recently, the menstrual cycle has become an object of special interest in sport sciences' studies, attempting to examine possible variations in the performance of athletes based on the phase of the cycle they are in. Hormonal variability, particularly in oestrogen and progesterone, can impact the response to exercise in women (Davis & Hackney, 2016). This raises the question of whether there are specific moments or phases in the menstrual cycle where performance differs. If so, taking the menstrual cycle into account during training could make a significant difference. Before delving deeper, it is necessary to gain a better understanding of the menstrual cycle, its phases, and the variability of the most crucial hormones. In fact, the participation of women in sports has experienced a remarkable increase, rising from 2% at the Paris Olympic Games in 1900 to 49% at the Tokyo 2020 Olympic Games (Committee, 2021). These has led to numerous research efforts in the field (McNulty et al., 2020).

Theoretically, a menstrual cycle lasts 28 days, but the normal range is between 21 and 35 days and can even extend up to 40 days (Serret et al., 2012). The menstrual cycle is divided into four phases based on the major hormonal changes that occur (Giménez-Blasi et al., 2022): Menstrual, follicular, ovulatory, and luteal (see Table 1).

Table 1. Phases of the menstrual cycle and key hormonal changes.

Phase	Hormonal changes
Menstrual (days 1 – 6)	Oestrogen and progesterone are low.
Follicular (days 7 – 12)	Oestrogen begins to rise, reaching its peak before ovulation.
Ovulatory (day 13 – 16)	As a result of the peak oestrogen at the end of the follicular phase, there is an increase in LH hormone that triggers the release of the egg from its follicle (ovulation).
Luteal (days 17 – 28)	Progesterone reaches its peak, and oestrogen has a noticeable increase midway through this phase.

Note: The duration range of each phase has been established using an ideal 28-day cycle as a representative reference.

The potential influence of the hormones on variations in athletic performance is based on the hypothesis of the anabolic and neuroexcitatory effects of oestrogen, contributing to the increase in strength and power levels, particularly during the follicular phase (Davis & Hackney, 2016). In contrast, during the luteal phase, higher levels of progesterone may inhibit cortical excitability and partially limit these benefits, potentially reducing performance capacity (Oosthuyse & Bosch, 2010).

The specific effects of hormonal phases on athletic performance provide a solid foundation for tailoring training plans to the menstrual cycle. During the follicular phase, increased levels of oestrogen are associated with enhanced strength production, power output, and recovery capacity, making it an optimal period for incorporating high-intensity exercises such as strength training, plyometrics, and explosive actions. Conversely, in the luteal phase, elevated progesterone levels can limit these capabilities by reducing neuromuscular efficiency and increasing perceived fatigue. As a result, training during this phase may benefit from a focus on moderate-intensity activities, technical skill development, and active recovery, ensuring performance is maintained without overburdening the athlete.

In women's basketball, the performance optimization process involves respect for fundamental principles of sports training, such as individualization and specificity (Bompa & Buzzichelli, 2018; Soto et al., 2023). Quantifying training load is an essential resource to obtain objective, valid, and useful information for the coaching staff regarding the performance of the players (Ibáñez & Feu, 2023). Those training programs have predominantly been designed considering the male sex, without addressing the physiological differences that may exist between men and women. It is evident that this has a negative impact on the preparation of female athletes, as training programs lack adaptability (Taylor et al., 2017). The wide hormonal variability that a woman may experience in her different cycles, coupled with significant differences between women, highlights the difficulty of establishing general training guidelines that are applicable to all players (Reed & Carr, 2000). Therefore, it is necessary to understand hormonal fluctuations and their implications on performance by analysing the performance of each athlete on an individualized basis, allowing to determine if the athlete experiences moments and phases where her performance is lower and adapt the training according to her individual response (McNulty et al., 2020).

Regarding strength training, Kissow et al. (2022) highlighted that training during the first half of the menstrual cycle appears to be superior in terms of improving strength and muscle mass. In this regard, Davis and Hackney (2016) conclude that poorer outcomes are expected at the end of the luteal phase and during the menstrual phase due to hormonal variations, especially in progesterone and oestrogen levels.

In relation to muscular endurance, anaerobic power, and hormonal changes, Arazi et al. (2019) did not find a performance loss in any of the evaluated capacities during different phases of the menstrual cycle. Additionally, the study by Romero-Moraleda et al. (2019) investigated fluctuations in muscular performance in the half-squat exercise and found no significant differences in the analysed variables between different phases of the cycle. However, Pallavi et al. (2017) examined variations in muscular strength and fatigue during menstrual cycle phases in young adult women. They concluded that cyclic hormonal variation increases muscular strength in the follicular phase. On the other hand, Julian et al. (2017) study focused on analysing the effects of different menstrual cycle phases on sub-elite female soccer players. A considerable decrease in Yo-Yo Test performance was observed during the latter half of the luteal phase compared to the menstrual phase, although similar effects were not found in jumps and sprints.

Based on the previous literature, most current studies on physical performance in women's basketball have overlooked the menstrual cycle of players or have considered it in laboratory conditions with isolated tests. These conditions differ significantly from a real training situation, especially in team sports like basketball, where factors and processes such as decision-making and environmental perception can impact the players' final performance (Grant et al., 2020). Consequently, it is advisable to investigate what happens in a real context, as evidenced, and carried out in recent research (Arenas-Pareja et al., 2023). The objective of this work was to analyse the impact of the menstrual cycle on the training load of basketball players in the actual training context, aiming to understand this relationship and identify the individual characteristics of each player.

MATERIALS AND METHODS

Design

This research was considered ex post facto following the classification of Montero and León (2007), due to the fact that the analysis of the data was carried out after its collection. This type of research is common in sport sciences due to the ecological context of data collection, being carried out in the natural context of sport without manipulation of variables or experimental design. The aim is to collect data as close as possible to what happens in reality, without interfering in the training or in the performance of the players. Therefore, none of the players' behaviours that could interfere with the results of the measurement are conditioned or modified. The players are expressly asked to maintain their daily habits and routines for the duration of the study as well as for the rest of the season. This ensures that, once the results are obtained, the conclusions and practical applications resulting from the research can be directly applied in training without modifying other issues.

Population and sample

This research was conducted with a team from that compete at national level. Twelve basketball players participated (age: 20.92 ± 4.72 years; height: 171.33 ± 8.60 cm) in this study. In the context of sports training, it is important to note that the number of players analysed is generally small due to the competitive nature of the environment. However, this inherent limitation in competitive sports does not compromise the validity of the results obtained (Lago-Peñas et al., 2019). Finally, only 10 players who met the inclusion criteria were included in the study.

Inclusion criteria

To be considered a case study, the player should: (i) belong to the analysed team; (ii) have participated in at least 70% of the training sessions; (iii) not take contraceptive pills, at least, in the last six months; (iv) have regular menstrual cycles; (v) not have suffered injuries in the last four weeks of training.

The information presented in this study comes from 8 training sessions: data were collected once a week for eight weeks (two months), this ensured that the structure of the session was very similar to reduce the contamination of the tasks design on the load generated. The tasks designs were developed by the team's coaching staff based on the sporting objectives, maintaining the same structure that they had been developing since the beginning of the season, with the same specific warm-up and full game tasks (5vs5). The duration of the sessions was 67.52 ± 14.80 minutes. The variability in the duration of the session is due to the distance to the match or the instructions of the coach.

Variables

The independent variable was the menstrual cycle, categorized into four levels based on the four phases of the cycle: Menstrual, Follicular, Ovulatory, and Luteal. Sixteen dependent variables were recorded (see Table 2), divided into two groups: internal load and external load. All of them considered the training session as a covariate.

Table 2. Summary of the variables analysed during the study.

		Variable	Description (measurement units)
Internal load		HRmax	Maximum heart rate (ppm).
		HRavg	Average heart rate (ppm).
		mhHR	Covered meters at >8 5% of maximum heart rate (m).
External load	Cinematic	mDEXP	Covered meters at > 1.12 m/s^2 (m).
		m1218	Covered meters at 12-18 km/h (m).
		m > 18	Covered meters at > 18 km/h (m).
		ACCmax	Numbers of accelerations at > 2 m/s^2 (n).
		DECmax	Numbers of decelerations at > 2 m/s^2 (n).
		ACCavg	Average acceleration (m/s^2).
		DECavg	Average deceleration (m/s^2).
		mhACC	Covered distance at > 3 m/s^2 (m).
		mhDEC	Covered distance at < -3 m/s^2 (m).
	Neuromuscular	hIMP	Impacts > 8 G (n).
		hTOFF	Take Offs > 3 G (n).
		hLAND	Landings > 5 G (n).
		PL	Player load (u. a.).

Instruments
Data recording was carried out using the WIMU Pro system (Agile Sports Technologies, Inc., Nebraska; Huld 2023). Ultra-wideband (UWB) technology was utilized for positioning, which records sports information indoors with greater measurement accuracy due to the placement of antennas (Figure 1). The UWB system is calibrated to the reference field by being distributed along the perimeter and recognizing it as the reference system (Bastida-Castillo et al., 2019).

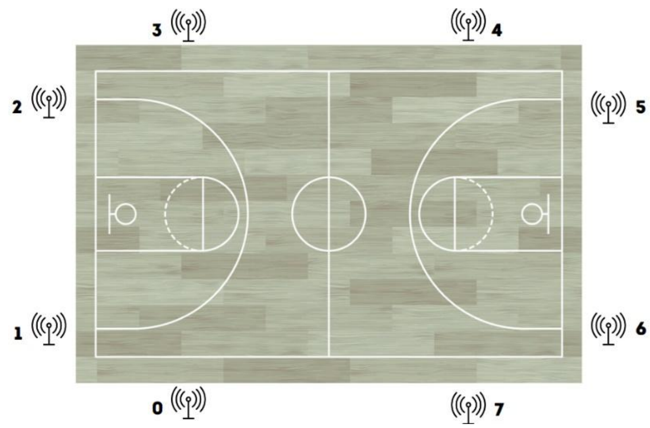


Figure 1. Distribution of the UWB antenna system on a basketball court (own elaboration).

Given that some of the mentioned methods for identifying the menstrual cycle phase tend to have higher economic costs, this research utilized a menstrual calendar mobile application. Consequently, the use of mobile applications for tracking menstrual cycles in elite athletes has become increasingly common. Various sports organizations, such as Chelsea Football Club, Brisbane Lions, and the U.S. national women's soccer and swimming teams, have adopted this methodology (Ayling, 2020; Kleyn, 2020). Athletes record their menstrual cycle and related symptoms, and coaches and the technical staff have access to this data to identify performance changes during different phases of the cycle. To maintain an accurate record of the menstrual cycle, the Clue application (Biowink GmbH, Germany) was used, which was familiarized with each player to keep individualized monitoring on their mobile device (Engelmann et al., 2018; Nogueira et al., 2018). This choice was based on its easy accessibility and feasibility, allowing for the recording of each stage of the menstrual cycle, as well as a range of physical, psychological, and activity changes from the first day of the cycle (Li et al., 2020; Palomino, 2021). In addition, the study by Liu et al. (2019) shows different studies regarding the validity of the app, as well as studying the menstrual cycle from a large amount of data extracted from the app.

The Clue app is the top-rated app on Android by users and the most downloaded, being widely used in scientific research (Liu et al., 2019). It consists of a menstruation calendar in which, through the collection of different data, a prediction of fertile days, menstrual cycles and ovulation is made; offering an analysis of past and current menstrual cycles. It is a tool that also works with adolescents and irregular menstrual cycles. For predictions it is necessary to add the dates of menstruation and intensity of flow, mood and premenstrual symptoms. It also allows you to record your physical activity, track your libido and record symptoms of premenstrual syndrome.

Procedure
All players and coaching staff were informed about the protocol to be followed. Similarly, any queries or concerns that arose were addressed, providing necessary clarifications. Informed consent was obtained from

all participants by signing a written document prior to data collection but after the protocol was reviewed by the Bioethics and Biosafety Commission of the University of Extremadura and approved on 19/12/2022 according to document 210/2022. The research was conducted following the ethical criteria of the Declaration of Helsinki (2013) and was approved by the University's Bioethics Committee (210/2022). Prior to the start of data collection, all players were interviewed to determine the status of their menstrual cycle. Details such as the current phase of the cycle, the duration of the last cycle, the use of oral contraceptives, cycle regularity, among other relevant aspects, were collected. Based on the obtained information, the selection of participating players was carried out.

Until now, most current studies on physical performance in women's basketball have overlooked the menstrual cycle of players or have considered it in laboratory conditions with isolated tests. These conditions differ significantly from a real training situation, especially in team sports like basketball, where factors and processes such as decision-making and environmental perception can impact the players' final performance (Grant et al., 2020). Consequently, it is advisable to investigate what happens in a real context, as evidenced and carried out in recent research (Arenas-Pareja et al., 2023).

To analyse each training session, the UWB system was calibrated approximately one hour before the start. In addition, the WIMU Pro inertial devices were synchronized with the UWB system using ANT+ technology. Each player received a GARMIN™ heart rate monitor and a WIMU Pro inertial device, which was placed in a specific anatomical harness adjusted on the upper back (Figure 2). This protocol was implemented before each training session, following a familiarization period during the first data collection session (García-Rubio et al., 2024).

Figure 2. Placement of the heart rate monitor and the inertial device (own elaboration). 1 and 2: Front view; 3: Rear view.

Data analysis

Firstly, normality in the distribution of the dependent variables was tested using the Shapiro-Wilk test ($p >$ .05). Secondly, the coefficient of variation (CV) was utilized to calculate the variability of each of the dependent variables and assess the relative dispersion of data at both the group and individual levels. In this case, the CV serves as an indicator of the homogeneity of a sample, as a smaller value indicates a more homogeneous sample. The dataset is considered homogeneous if the coefficient of variation is less than or equal to 30%; however, if the coefficient of variation is greater, the dataset is deemed heterogeneous (Field, 2013).

Next, a Mixed Linear Model (MLM) was applied to consider the fixed effects of the menstrual cycle, as well as the random effects capturing individual differences and variations among team players. Within the random effects, the Intraclass Correlation Coefficient (ICC) was considered. The ICC is typically calculated as the ratio of between-group variance to the sum of variances between groups and within groups. It can be interpreted as the proportion of total variation explained by the grouping structure of the model. In this case, the ICC allows us to understand what amount of variation can be explained by differences among the team players. Similarly, linear regression was used as a statistical technique to estimate the magnitude and direction of the menstrual cycle effects individually for each player on the internal and external load endured. This can help us understand the relationships between the studied variables and draw conclusions about the impact of the menstrual cycle on performance at an individual level. In both analyses, the training session was consistently considered as a covariate. All statistical analyses were conducted using the software Jamovi 2.3.18 (The Jamovi Project, 2022). The significance level was set at $p < .05$.

RESULTS

Based on the data recorded in the mobile application used by each player, the following information was obtained from our sample: participants have an average cycle duration of 31.35 days, with a standard deviation of ±5.12 days. Next, the results of the descriptive and variability analysis of the investigated variables at the group level are presented in Table 3.

Table 3. Descriptive and variability analysis of external and internal load indicators at the group level.

		Variable	X	SD	CV (%)
Internal load		HRmax	184.82	13.89	8
		HRavg	143.58	16.39	11
		mhHR	1386.73	834.01	**60**
External load	Cinematic	mDEXP	342.16	88.82	26
		m1218	453.13	164.12	**36**
		m > 18	34.68	31.41	**91**
		ACCmax	4.71	1.33	28
		DECmax	(-)4.74	(-)1.12	24
		ACCavg	0.74	0.10	14
		DECavg	(-)0.74	(-)0.09	12
		mhACC	71.39	37.19	**52**
		mhDEC	74.20	32.83	**44**
	Neuromuscular	hIMP	26.04	18.02	**69**
		hTOFF	5.38	4.42	**82**
		hLAND	8.86	9.44	**107**
		PL	58.70	10.87	19

Note: Distance covered at > 1.12m/s² (mDEXP); Distance covered at 12-18km/h (m1218); Distance covered at over 18km/h (m > 18); Maximum acceleration (ACCmax); Maximum deceleration (DECmax); Average acceleration (ACCavg); Average deceleration (DECavg); Distance covered at > 3m/s² (mhACC); Distance covered at > -3m/s² (mhDEC); Maximum heart rate (HRmax); Average heart rate (HRavg); Distance covered at > 85% of maximum heart rate (mhHR); Impacts > 8G (hIMP); Take-offs > 3G (hTOFF); Landings > 5G (hLAND); Neuromuscular load (PL). Values with a Coefficient of Variation (CV) greater than 30% have been highlighted in bold.

Analysing the Coefficient of Variation (CV) of the recorded variables, it is observed that landings above 5G (hLAND) exceed 100% variation, followed by distance covered at over 18km/h (m > 18) with 91%, and take-offs above 3G (hTOFF) with a variability of 81%.

Table 4 shows the results obtained from the evaluation of relative dispersion through the coefficient of variation in the analysed variables for each player.

Table 4. Variability analysis of external and internal load indicators at the individual level.

Variables			CV									
			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
		HRmax	3	16	5	1	1	3	2	15	1	4
Internal load		HRavg	8	19	5	6	3	5	8	18	4	6
		mhHR	**64**	**95**	**81**	**34**	27	**48**	**48**	**56**	24	**50**
		mDEXP	27	**39**	17	24	5	22	25	19	15	22
		m1218	29	**66**	26	26	9	**39**	29	29	**31**	**32**
		m > 18	**93**	**99**	**60**	**123**	**81**	**61**	**37**	**83**	**145**	**85**
		ACCmax	**31**	**41**	22	**40**	16	**31**	15	**32**	13	20
	Cinematic	DECmax	26	**31**	19	**39**	15	24	9	25	9	13
		ACCavg	15	12	8	12	7	9	13	8	6	7
External load		DECavg	17	12	6	12	6	8	12	8	6	6
		mhACC	**48**	**76**	28	**42**	27	28	**39**	**43**	**64**	29
		mhDEC	**57**	**46**	24	**46**	24	**39**	**34**	24	**45**	**51**
		hIMP	**43**	**96**	**34**	**57**	**31**	**48**	**54**	**45**	**48**	**58**
	Neuromuscular	hTOFF	**57**	**122**	**50**	**146**	**95**	**46**	**57**	**78**	**55**	**67**
		hLAND	**60**	**86**	**50**	**54**	**68**	**35**	**51**	**138**	**48**	**87**
		PL	18	27	12	19	9	9	22	14	9	9

Note: Player (P); Distance covered at > 1.12m/s² (mDEXP); Distance covered at 12-18km/h (m1218); Distance covered at over 18km/h (m > 18); Maximum acceleration (ACCmax); Maximum deceleration (DECmax); Average acceleration (ACCavg); Average deceleration (DECavg); Distance covered at > 3m/s² (mhACC); Distance covered at > -3m/s² (mhDEC); Maximum heart rate (HRmax); Average heart rate (HRavg); Distance covered at > 85% of maximum heart rate (mhHR); Impacts > 8G (hIMP); Take-offs > 3G (hTOFF); Landings > 5G (hLAND); Neuromuscular load (PL). Values with a Coefficient of Variation (CV) greater than 30% have been highlighted in bold.

The individual results reveal that players 5 and 3 exhibit the least performance variation in the recorded variables, as their Coefficient of Variation (CV) exceeds 30% in only 4 out of 16 variables and in 5 out of 16 variables, respectively. For player 5, the variable hTOFF (take-offs > 3G) has the highest CV at 95%. In contrast, player 3 records the highest CV in the variable mhHR (distance covered at more than 85% of her maximum heart rate) with a value of 81%. On the other hand, player 2 shows the greatest variation in performance, with a CV exceeding 30% in 11 out of the 16 collected variables, and the variable hTOFF (take-offs > 3G) exhibits the highest variability at 122%.Four variables stand out, with all players exceeding 30% in Coefficient of Variation (CV): Distance covered at over 18km/h (m > 18); Impacts > 8G (hIMP); Take-offs > 3G (hTOFF); Landings > 5G (hLAND). In three of these four variables (m > 18, hTOFF, and hLAND), at least one player records a CV higher than 100%.

Regarding the mixed linear model, the results are presented in Table 5. In the model, the menstrual cycle phase explains 40%, 34%, and 41% of the total variability in performance for average acceleration (ACCavg), average deceleration (DECavg), and distance covered at > 85% of the maximum heart rate (mhHR), respectively. Simultaneously, the Intraclass Correlation Coefficient (ICC) indicates that individual differences between players account for approximately 38%, 33%, and 40% of the total variability in average acceleration (ACCavg), average deceleration (DECavg), and distance covered at > 85% of the maximum heart rate (mhHR), respectively. This suggests that both the menstrual cycle phase and individual player characteristics are important factors to consider when analysing team performance.

Further below, you can observe the results obtained from the linear regression analysis (see to Table 6), which examines the impact of the menstrual cycle on the performance variation of each player.

Table 5. Results of the mixed linear model.

		Variable	**R^2 conditional**	***p*-Value**	**ICC**
Internal load		HRmax	.01	.98	0.00
		HRavg	.32	.40	0.30
		mhHR	**.41**	.04*	0.40
External load	Kinematic	mDEXP	.27	.20	0.24
		m1218	.18	.82	0.18
		m > 18	.29	.85	0.27
		ACCmax	.10	.44	0.00
		DECmax	.11	.33	0.00
		ACCavg	**.40**	.01*	0.38
		DECavg	**.34**	.01*	0.33
		mhACC	.29	.43	0.28
		mhDEC	.30	.29	0.28
	Neuromuscular	hIMP	.47	.39	0.45
		hTOFF	.27	.69	0.25
		hLAND	.41	.69	0.39
		PL	.24	.21	0.21

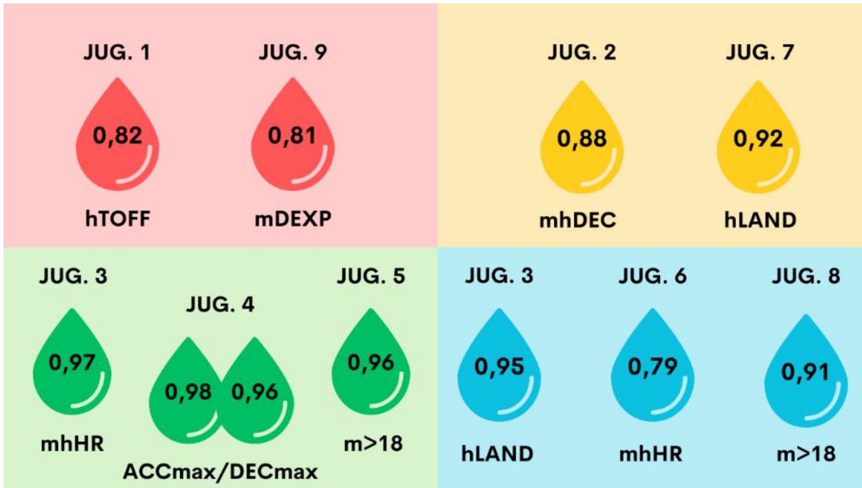
Note: Distance covered at > 1.12m/s² (mDEXP); Distance covered at 12-18km/h (m1218); Distance covered at over 18km/h (m > 18); Maximum acceleration (ACCmax); Maximum deceleration (DECmax); Average acceleration (ACCavg); Average deceleration (DECavg); Distance covered at > 3m/s² (mhACC); Distance covered at > -3m/s² (mhDEC); Maximum heart rate (HRmax); Average heart rate (HRavg); Distance covered at > 85% of maximum heart rate (mhHR); Impacts > 8G (hIMP); Take-offs > 3G (hTOFF); Landings > 5G (hLAND); Neuromuscular load (PL). Conditional R2 values that are statistically significant, indicated by a p-value < .05 (*), have been highlighted in bold.

Table 6. Regression analysis results.

Variables			**CV**									
			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Internal load		HRmax										
		HRavg										
		mhHR			0.97			0.79				
External load	Kinematic	mDEXP									0.81	
		m1218										
		m > 18					0.96			0.91		
		ACCmax				0.98						
		DECmax				0.96						
		ACCavg										
		DECavg										
		mhACC										
		mhDEC		0.88								
	Neuromuscular	hIMP										
		hTOFF	0.82									0.82
		hLAND			0.95				0.92			
		PL										

Note: Distance covered at > 1.12m/s² (mDEXP); Distance covered at 12-18km/h (m1218); Distance covered at over 18km/h (m > 18); Maximum acceleration (ACCmax); Maximum deceleration (DECmax); Average acceleration (ACCavg); Average deceleration (DECavg); Distance covered at > 3m/s² (mhACC); Distance covered at > -3m/s² (mhDEC); Maximum heart rate (HRmax); Average heart rate (HRavg); Distance covered at > 85% of maximum heart rate (mhHR); Impacts > 8G (hIMP); Take-offs > 3G (hTOFF); Landings > 5G (hLAND); Neuromuscular load (PL). The menstrual cycle phase in which performance is superior is indicated by colours: Red: Menstrual; Yellow: Follicular; Green: Ovulation; Blue: Luteal. In colour: Variables where R2 has proven to be significant for each player.

Following, in Figure 3, the significant results shown in the previous table are visually represented through a linear regression analysis.



Note: Distance covered at > 1.12m/s² (mDEXP); Distance covered at over 18km/h (m > 18); Maximum acceleration (ACCmax); Maximum deceleration (DECmax); Distance covered at > -3m/s² (mhDEC); Distance covered at > 85% of maximum heart rate (mhHR); Take-offs > 3G (hTOFF); Landings > 5G (hLAND). The menstrual cycle phase is indicated by colours: Red: Menstrual; Yellow: Follicular; Green: Ovulation; Blue: Luteal.

Figure 3. Variables where R2 has proven to be significant for each player.

For instance, in the case of Player 1, 82% of the variability in take-offs above 3G can be explained by the menstrual cycle phase. Performance is significantly higher in the bleeding phase compared to the follicular phase. Regarding Player 2, 88% of the variability in distance covered at speeds greater than -3m/s² can be explained by the menstrual cycle phase. Performance is significantly higher in the follicular phase compared to the other phases. The menstrual cycle phase explains 97% of the variability in distance covered at over 85% of the maximum heart rate for Player 3, with significantly better performance in the ovulatory phase compared to the luteal phase.

DISCUSSION

The purpose of this research was to analyse the effects of the menstrual cycle on the variability of training load in female basketball players within the real training context, as well as to identify aspects to consider in the athletes' physical preparation. Therefore, it is crucial to understand which performance capacities are affected by players' biological conditions. Previous studies have indicated that performance may vary depending on the phase of the menstrual cycle, either improving or decreasing (Davis & Hackney, 2016; Grant et al., 2020; Ramos, 2022). The results of this study highlight the influence of the menstrual cycle phase on the variation of sports performance and the considerable hormonal variability at the individual level associated with this menstrual cycle. It has been observed that the menstrual cycle has an impact on sports performance (Kissow et al., 2022). Specifically, one would expect to find poorer results in the luteal phase and menstrual phase due to variations in hormones, including both progesterone and oestrogen (Marugán, 2019). The decrease in both hormones is likely responsible for this performance decline, indicating that the body is not prepared to reach its maximum level. On the other hand, in the follicular phase, hormone levels increase, preparing the body to face more intense loads. In fact, some studies have demonstrated significantly better performance in intermittent endurance and muscle strength during the follicular phase compared to the luteal phase (Graja et al., 2022; Pallavi et al., 2017). Specifically, variables related to accelerations, decelerations, and explosive actions have been affected (Arenas-Pareja et al., 2023). These variables, along with jumps, are crucial in basketball performance (Hulka et al., 2014; Reina et al., 2019; Taylor et al., 2017).

Various studies have revealed that there is no clear trend for all female athletes in terms of sports performance during different phases of the menstrual cycle. Specifically, it has been found that performance was not affected by the menstrual cycle, but associated pains decreased during training and competition (Kishali et al., 2006). In another study, no trends were observed in performance when comparing the luteal and follicular phases. In fact, analysing days with and without menstruation, performance either increased or decreased (Tremback-Ball et al., 2021). Furthermore, when female athletes report their own sensations regarding performance during the menstrual cycle, 80% conclude that the menstrual cycle decreases performance in each cycle (Farage et al., 2009). On the other hand, some athletes, approximately 37%, perceive that they feel stronger, more motivated, and prepared to exert effort during the late follicular phase, ovulation (Michelekaki et al., 2023). In the present study, the various analysed variables exhibit different behaviours during the menstrual cycle both at the group level and individually.

The results of individuality through the MLM reveal variables with 0% individuality (HRmax, Accmax, Decmax) and variables with a great individual affectation, where the differences are explained by the different menstrual cycle in each subject by 35% or more (mhHR, Accavg, hIMP, hLand). These results indicate that for the variables of volume and neuromuscular intensity, each player will respond differently depending on the phase of the cycle in which she is, while the variables of maximum intensity are not affected by the differences between menstrual cycles of each player. Therefore, for a greater generalisation of training in team sports, the maximum values of internal load and kinematic external load should be observed. For a greater individualisation of the training load, the volume and maximum neuromuscular intensity variables should be observed.

Within the individual variability of athletes, the results show players who improve their performance in different phases of the menstrual cycle and even some who remain constant throughout the entire menstrual cycle. It is known that the duration of the menstrual cycle, the length of the phases, and the timing of the LH peak vary significantly among individuals. Additionally, ovulation and the peak of progesterone in the mid-luteal phase do not occur in every cycle for all women (Reed & Carr, 2000). The data obtained suggest that, to achieve the maximum performance of athletes, emphasis should be placed on the individuality of each team player, with the goal of building a personalized and effective training program that ensures optimal performance without compromising individual capacities or leading to excessive effort, as already suggested by McNulty et al. (2020).

The results of the present study reveal variations in intra-subject physical performance explained in more than 90% by the menstrual cycle in several female players, in variables such as falls, distance covered at high intensity and maximum accelerations and decelerations. Other studies (Gasperi et al., 2023) show how the menstrual cycle affects other essential components of basketball, such as technique and tactics, significantly. This results in greater irregularity in performance, which is evident in team sports such as basketball (Scanlan et al., 2012). Coaches should take into account the fluctuations in the menstrual cycle of their players when planning their weekly match schedule, bearing in mind that there may be occasional drops in the performance of players who are on a good trajectory.

The study presents a small sample due to the ecological nature of the study. Nevertheless, the results align with findings in the literature. Instead, the results indicate the need to focus on the individual aspect of the menstrual cycle (Laus, 2020), given the significant variability in players' outcomes. To achieve this, it is recommended to maintain a daily record allowing the adaptation of training sessions according to the phase of the menstrual cycle the player is in. In this way, it will be possible to understand how each phase affects performance and precisely adjust the training. In this context, it is interesting to establish a general structure for physical preparation considering the menstrual cycle of each player, following Bataller's proposal (Marugán, 2019). This would involve identifying, for each player, the most suitable moments for training focused on speed, explosiveness, strength, and maximum strength. Additionally, efforts would be made to measure peaks of maximum performance and adapt training to lower intensities during phases with reduced fatigue tolerance. During these periods, the recommendation is to focus on cardiovascular training within the range of the minimum effective volume and maximum adaptative volume. Another limitation is the lack of control for contaminant variables. The choice of ecological studies allows a closer approach to the real context, measuring and assessing what really happens in the sport, however, it makes you assume a greater influence of contaminating factors that require more robust statistical analyses to ensure that these contaminating variables do not influence, or influence as little as possible, the results found. This approach will make it easier for coaches to apply science in their training, as in day-to-day training it is impossible to isolate players from contaminating variables and they must live with these influences that condition behaviour, especially in experimental sciences with humans.

CONCLUSIONS

In summary, the findings of this research underscore the importance of considering the menstrual cycle in the planning and customization of training in women's basketball. The physical performance of players in relation to training load exhibited a significant level of variability, partly due to the menstrual cycle phase, which was considered a relevant variable in this study.

The integration of specific strategies based on menstrual cycle phases is a key factor for optimizing player performance by adjusting training loads, intensities, and approaches according to individual needs. For example, focus in the follicular phase on high intensity and explosive aspects; in the luteal phase on more tactical aspects with a lower physical load and the menstrual phase focusing on low impact exercises and active recovery. Also, during competitions the technical staff can take decisions about playing time of each player according to this information.

The individuality of each athlete is a key factor, as the response to the menstrual cycle can vary. It is therefore advisable a call to action to implement individualized menstrual cycle recordings in sports teams, supported by accessible technology such as mobile apps, to adapt training optimally, maximising performance during the most favourable phases and minimising the risk of fatigue in the less favourable ones.

Practical applications

Based on the findings of this study and the recommendations from the literature, it is possible to establish practical guidelines for adapting training sessions to the menstrual cycle phases, ensuring optimal performance and minimizing the risk of overtraining or injury. During the follicular phase, when hormonal levels, particularly oestrogen, are elevated, athletes may benefit from prioritizing high-intensity training focused on explosive actions, strength development, and speed. This phase is particularly suited for incorporating maximal strength training and plyometric exercises, given the body's enhanced tolerance to physical stress. In contrast, during the luteal phase and menstrual phase, when hormonal fluctuations, especially increased progesterone and decreased oestrogen, can negatively affect performance and recovery, training loads should be adjusted accordingly. Coaches may focus on moderate-intensity cardiovascular exercises, technical skill development, and tactical sessions to maintain performance while reducing physical and psychological fatigue. Additionally, periods of intense pain or discomfort may call for further individualization, such as active recovery sessions or flexibility exercises. To implement these adaptations effectively, it is essential to maintain individual monitoring of each player's cycle and use this data to personalize training loads. Establishing this structure allows teams to enhance athletes' performance while addressing the physiological demands associated with their menstrual cycle.

As it is a team sport, it can sometimes be difficult to carry out sessions according to the menstrual cycle. If this is not possible, the ideal would be to adapt each player to the session. In particular, the players‘ rest periods can be modified, regulating the series in which each player takes part and modifying the rotations according to the players' needs. It is possible to prioritise the intervention of some players in certain tasks, participating more or less time in the tasks depending on whether they are more or less aerobic, with a greater or lesser impact load. Also, instead of grouping players by specific positions when training, groupings can be made according to training needs in certain high intensity tasks. The rest of the stimuli should be dealt with in the physical preparation or gym sessions, where each player can be individualised and it is easier to attend to the individual needs of each player.

In terms of competition, priority should be given to performance in those categories in which the players are already formed. To this end, sometimes it will not be possible to pay attention to the individuality of the players, but as far as possible with open scores in favour of the team, rotations established by the physical trainer after a load control must be respected in order to correctly manage the recovery periods necessary for a correct adaptation to the training and competition processes and to avoid overloads or risk of injury. In addition, training must also be adapted to what happens in competition. Those players with a deficit of playing time in competition, due to the coach's decision, will have to do compensatory sessions, attending to each of their needs. In other words, if in their phase they require a more power-focused load, they should compensate for the time not played with power-related activities. Therefore, this compensatory work should be modified weekly.

AUTHOR CONTRIBUTIONS

Conceptualization: M. d. l. A., P.L.S., S.J.I., J.G.R.; Data curation: M. d. l. A., J.G.R.; Formal analysis: M. d. l. A., J.G.R.; Funding acquisition: P.L.S., S.J.I., J.G.R.; Investigation: M. d. l. A., P.L.S.; Methodology: J.G.R.; Project administration: S.J.I., J.G.R.; Resources: S.J.I.; Software: S.J.I., J.G.R.; Supervision: J.G.R.; Validation: P.L.S., S.J.I.; Visualization: P.L.S.; Writing – original draft: M. d. l. A., J.G.R.; Writing – review & editing: P.L.S., S.J.I.

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No potential conflict of interest was reported by the authors.

REFERENCES

Arazi, H., Nasiri, S., & Eghbali, E. (2019). Is there a difference toward strength, muscular endurance, anaerobic power and hormonal changes between the three phase of the menstrual cycle of active girls? Apunts Med Esport, 54(202), 65-72. https://doi.org/10.1016/j.apunts.2018.11.001

Arenas-Pareja, M. D., López-Sierra, P., Ibáñez, S. J., & García-Rubio, J. (2023). Influence of Menstrual Cycle on Internal and External Load in Professional Women Basketball Players. Healthc, 11(6), Article 822. https://doi.org/10.3390/healthcare11060822

Ayling, L. (2020). How Women's Menstrual Cycle Affects AFL Performance-Brisbane Lions Use App to Design Training According to Players' Time of the Month.

Bastida-Castillo, A., Gómez-Carmona, C. D., De la Cruz-Sánchez, E., Reche-Royo, X., Ibáñez, S. J., & Ortega, J. P. (2019). Accuracy and Inter-Unit Reliability of Ultra-Wide-Band Tracking System in Indoor Exercise. Appl Sci, 9(5), Article 939. https://doi.org/10.3390/app9050939

Bompa, T. O., & Buzzichelli, C. (2018). Periodization: Theory and Methodology of Training (H. Kinetics, Ed. 6th ed.). https://doi.org/10.5040/9781718225435

Committee, I. O. (2021). Gender equality through time.

Davis, H., & Hackney, A. (2016). Hormonas sexuales, ejercicio y mujeres: aspectos científicos y clínicos (Springer, Ed.).

Engelmann, L., Signoretti, I., Prestes, M., Larréa, V., & Silveira, M. (2018). Como está o seu ciclo menstrual? Uma Avaliação de Comunicabilidade e Percurso Cognitivo do Aplicativo Clue XVII Simpósio Brasileiro sobre Fatores Humanos em Sistemas Computacionais. https://doi.org/10.5753/ihc.2018.4205

Farage, M. A., Neill, S., & MacLean, A. B. (2009). Physiological Changes Associated with the Menstrual Cycle: A Review. Obstet Gynecol Surv, 1, 58-72. https://doi.org/10.1097/OGX.0b013e3181932a37

Field, A. (2013). Discovering Statistics using IBM SPSS Statistics (M. Carmichael, Ed. 4th ed.). Sage.

García-Rubio, J., López-Sierra, P., Reina, M., & Ibáñez, S. J. (2024). Internal and external load profiles of male basketball players during training. J. Sports Eng. Technol., 0. https://doi.org/10.1177/17543371241231033

Gasperi, L., Sansone, P., Gómez-Ruano, M. A., Lukonaitiene, I., & Conte, D. (2023). Female basketball game performance is influenced by menstrual cycle phase, age, perceived demands and game-related contextual factors. J. Sports Sci. https://doi.org/10.1080/02640414.2023.2285119

Giménez-Blasi, N., Latorre, J. A., Martínez-Bebia, M., Sáenz, M., Cantero, L., López-Moro, A., . . . Mariscal-Arcas, M. (2022). Menstrual Cycle and Sport: effects on the performance and metabolism of the athlete woman. Retos (46), 565-572. https://doi.org/10.47197/retos.v46.94614

Graja, A., Kacem, M., Hammouda, O., Borji, R., Bouzid, M. A., Souissi, N., & Rebai, H. (2022). Physical, Biochemical, and Neuromuscular Responses to Repeated Sprint Exercise in Eumenorrheic Female Handball Players: Effect of Menstrual Cycle Phases. J. Strength Cond Res, 36(8), 2268-2276. https://doi.org/10.1519/JSC.0000000000003556

Grant, L. K., Gooley, J. J., St Hilaire, M. A., Rajaratnam, S. M. W., Brainard, G. C., Czeisler, C. A., . . . Rahman, S. A. (2020). Menstrual phase-dependent differences in neurobehavioral performance: the role of temperature and the progesterone/estradiol ratio. Sleep, 43(2), Article zsz227. https://doi.org/10.1093/sleep/zsz227

Hulka, K., Cuberek, R., & Svoboda, Z. (2014). Time-motion analysis of basketball players: a reliability assessment of Video Manual Motion Tracker 1.0 software. J Sports Sci, 32(1), 53-59. https://doi.org/10.1080/02640414.2013.805237

Ibáñez, S. J., & Feu, S. (2023). Sobre la bocina. Aplicaciones prácticas sobre los resultados de investigación sobre balonesto. Editorial Wanceulen.

Julian, R., Hecksteden, A., Fullagar, H. H. K., & Meyer, T. (2017). The effects of menstrual cycle phase on physical performance in female soccer players. Plos One, 12(3), Article e0173951. https://doi.org/10.1371/journal.pone.0173951

Kishali, N. F., Imamoglu, O., Katkat, D., Atan, T., & Akyol, P. (2006). Effects of menstrual cycle on sports performance. Int J Neurosci, 116(12), 1549-1563. https://doi.org/10.1080/00207450600675217

Kissow, J., Jacobsen, K. J., Gunnarsson, T. P., Jessen, S., & Hostrup, M. (2022). Effects of Follicular and Luteal Phase-Based Menstrual Cycle Resistance Training on Muscle Strength and Mass. Sports Med, 52(12), 2813-2819. https://doi.org/10.1007/s40279-022-01679-y

Kleyn, B. (2020). Los ciclos menstruales mapeados por una aplicación ayudan a los entrenadores a mejorar el rendimiento de sus equipos. ACB.

Lago-Peñas, C., Lorenzo-Calvo, A., Cárdenas, D., Alarcón, F., Ureña, A., Giménez Fuentes-Guerra, F., . . . Ortega-Toro, E. (2019). La creación de conocimiento en los deportes de equipo. Sobre el tamaño de la muestra y la generalización de los resultados. Jump, 1, 7-8. https://doi.org/10.17561/jump.n1.e

Laus, B. (2020). Entrenamientos Planificados Según el Ciclo Menstrual. In B. A. Universidad de Buenos Aires, Argentina (Ed.).

Li, K., Urteaga, I., Wiggins, C. H., Druet, A., Shea, A., Vitzthum, V. J., & Elhadad, N. (2020). Characterizing physiological and symptomatic variation in menstrual cycles using self-tracked mobile-health data. NPJ digit med, 3, 79. https://doi.org/10.1038/s41746-020-0269-8

Liu, B., Shi, S. Y., Wu, Y. S., Thomas, D., Symul, L., Pierson, E., . . . Assoc Comp, M. (2019, May 13-17). Predicting pregnancy using large-scale data from a women's health tracking mobile application. [Web conference 2019: Proceedings of the world wide web conference (www 2019)]. World Wide Web Conference (WWW), San Francisco, CA. https://doi.org/10.1145/3308558.3313512

Marugán, B. (2019). El deporte femenino, ese gran desconocido (I. U. d. E. d. G. Universidad Carlos III de Madrid, Ed.). UC3M.

McNulty, K. L., Elliott-Sale, K. J., Dolan, E., Swinton, P. A., Ansdell, P., Goodall, S., . . . Hicks, K. M. (2020). The Effects of Menstrual Cycle Phase on Exercise Performance in Eumenorrheic Women: A Systematic Review and Meta-Analysis. Sports Med, 50(10), 1813-1827. https://doi.org/10.1007/s40279-020-01319-3

Michelekaki, E. A., Michaelides, M., Govindasamy, K., & Parpa, K. (2023). Recreational Female Athletes' Understanding of and Perceived Impact of the Menstrual Cycle on Physical Performance, Mood, and Sleeping Behaviour. Women, 3, 445-456. https://doi.org/10.3390/women3030034

Montero, I., & León, O. G. (2007). A guide for naming research studies in Psychology. Int J Clin Health Psychol, 7(3), 847-862.

Nogueira, B., Queiroz, E., Nobre, J., Araújo, M., & Monteiro, I. (2018). Avaliando a Usabilidade e a Experiência de Uso de Aplicativos de Acompanhamento do Ciclo Menstrual Anais Estendidos do XVII Simpósio Brasileiro sobre Fatores Humanos em Sistemas Computacionais. https://doi.org/10.5753/ihc.2018.4203

Oosthuyse, T., & Bosch, A. N. (2010). The effect of the menstrual cycle on exercise metabolism: implications for exercise performance in eumenorrheic women. Sports Med, 40, 207-227. https://doi.org/10.2165/11317090-000000000-00000

Pallavi, L. C., Souza, U. J. D., & Shivaprakash, G. (2017). Assessment of Musculoskeletal Strength and Levels of Fatigue during Different Phases of Menstrual Cycle in Young Adults. J Clin Diagn Res, 11(2), CC11-CC13. https://doi.org/10.7860/JCDR/2017/24316.9408

Palomino, V. E. (2021). Ciclo menstrual y su relación con la fuerza en voleibolistas categoría mayores, Cajamarca. In Trabajo Fin de Grado: Universidad César Vallejo.

Ramos, B. A. (2022). Influencia del ciclo menstrual sobre la resistencia aeróbica en mujeres entrenadas que asisten a un gimnasio de Trujillo. In Trabajo Fin de Grado: Universidad César Vallejo, Perú.

Reed, B. G., & Carr, B. R. (2000). The Normal Menstrual Cycle and the Control of Ovulation. In K. R. Feingold, B. Anawalt, M. R. Blackman, A. Boyce, G. Chrousos, E. Corpas, W. W. de Herder, K. Dhatariya, K. Dungan, J. Hofland, S. Kalra, G. Kaltsas, N. Kapoor, C. Koch, P. Kopp, M. Korbonits, C. S. Kovacs, W. Kuohung, B. Laferrère, M. Levy, E. A. McGee, R. McLachlan, M. New, J. Purnell, R. Sahay, A. S. Shah, F. Singer, M. A. Sperling, C. A. Stratakis, D. L. Trence, & D. P. Wilson (Eds.), Endotext. MDText.com, Inc.

Reina, M., García-Rubio, J., Pino-Ortega, J., & Ibáñez, S. J. (2019). The Acceleration and Deceleration Profiles of U-18 Women's Basketball Players during Competitive Matches. Sports, 7(7), Article 165. https://doi.org/10.3390/sports7070165

Romero-Moraleda, B., Del Coso, J., Gutiérrez-Hellín, J., Ruiz-Moreno, C., Grgic, J., & Lara, B. (2019). The Influence of the Menstrual Cycle on Muscle Strength and Power Performance. J Human Kinet, 68(1), 123-133. https://doi.org/10.2478/hukin-2019-0061

Scanlan, A. T., Dascombe, B. J., Reaburn, P., & Dalbo, V. J. (2012). The physiological and activity demands experienced by Australian female basketball players during competition. J Sci Med Sport, 15(4), 341-347. https://doi.org/10.1016/j.jsams.2011.12.008

Serret, J., Hernández, A., Mendoza, O., Cárdenas, R., & Villasis, M. A. (2012). Alteraciones menstruales en adolescentes [Menstrual disorders in adolescents]. Bol méd Hosp Inf Méx, 69(1), 63-76.

Soto, D., Diaz, J., Bautista, I. J., & & Martinez, I. (2023). Effects of a Strength Training Protocol with Self-loading and Plyometry on Handball Physical Performance: First National Female Category. E-bm Com, 18(2), 83-92. https://doi.org/10.17398/1885-7019.18.83

Taylor, J. B., Wright, A. A., Dischiavi, S. L., Townsend, M. A., & Marmon, A. R. (2017). Activity Demands During Multi-Directional Team Sports: A Systematic Review. Sports Med, 47(12), 2533-2551. https://doi.org/10.1007/s40279-017-0772-5

Tremback-Ball, A., Fulton, K., Giampietro, N., Gibbons, M., Kneller, A., & Zelinka, H. (2021). Effect of the menstrual cycle on athletic performance in NCAA Division III collegiate athletes. J Women Health Phys Ther, 45, 20-26. https://doi.org/10.1097/JWH.0000000000000188