Original article

Influence of the menstrual cycle on physical and cognitive performance in eumenorrheic women

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Summary

Introduction: The female sexual hormones typical of the menstrual cycle not only have reproductive functions, they also influence other physiological systems and can affect sports and cognitive performance. The purpose of this study has been to evaluate different aspects such as body composition, endurance, muscle strength and some cognitive abilities at different stages of the menstrual cycle.
Material and method: Eight young eumenorrheic women (age = 23.1 ± 4.4 years) with regular menstrual cycles participated in the study. A densitometry and bioimpedance test were performed to study body composition, a short-term visual memory test and a reaction time test to assess cognitive abilities, and muscle characteristics (thickness and stiffness of the anterior rectus and muscle strength) along with a progressive test to exhaustion were analyzed to assess performance during the mid-follicular (FF) and mid-luteal (FL) phases of the participants' menstrual cycle.
Results: During the follicular phase, the participants registered a greater total time (FF = 488.5 ± 93.18 s vs. FL = 468.6 ± 81.29 s; $P = 0.015$) and a lower initial heart rate (FF = 83.3 ± 10.23 PPM vs. FL = 92.9 ± 7.67 PPM; $P = 0.034$) in the progressive test to exhaustion. Regarding cognitive abilities, in the follicular phase, better results were obtained in reaction time both with the right hand (FF = 0.426 ± 0.082 s vs. FL = 0.453 ± 0.087 s; $P = 0.036$) and with the left hand (FF = 0.435 ± 0.096 s vs. FL = 0.466 ± 0.077 s; $P = 0.034$). On the other hand, a higher percentage of fat (FF = 27.3 ± 5.1% vs. FL = 27.9 ± 5.0%; $P = 0.041$) was found in the luteal phase.
Conclusion: Performance in endurance and in cognitive test, such as reaction time was better in the Follicular Phase, while a higher percentage of fat was observed in the Luteal Phase. However, memory, strength and muscular characteristics were not affected by the hormonal fluctuations of the menstrual cycle.

Key words:
Menstrual cycle. Woman. Cognitive aspects. Performance. Physical activity.

Influencia del ciclo menstrual en el rendimiento físico y cognitivo en mujeres eumenorreicas

Resumen

Introducción: Las hormonas sexuales femeninas propias del ciclo menstrual no solo tienen funciones reproductivas, también influyen en otros sistemas fisiológicos pudiendo afectar al rendimiento deportivo y cognitivo. El propósito del presente estudio ha sido evaluar distintos aspectos como la composición corporal, la resistencia, la fuerza muscular y algunas capacidades cognitivas en diferentes etapas del ciclo menstrual.
Material y método: En el estudio participaron ocho mujeres jóvenes eumenorreicas (edad = 23,1 ± 4,4 años) con ciclos menstruales regulares. Se realizó una prueba de densitometría y una bioimpedancia para estudiar la composición corporal, una prueba de memoria visual a corto plazo y un test de tiempo de reacción para evaluar habilidades cognitivas y se analizaron características del músculo (grosor y rigidez del recto anterior y fuerza muscular) junto a una prueba de esfuerzo para evaluar el rendimiento durante las fases folicular media (FF) y lútea media (FL) del ciclo menstrual de las participantes.
Resultados: Durante la fase folicular las participantes registraron un mayor tiempo total (FF = 488,5 ± 93,18 s vs. FL = 468,6 ± 81,29 s; p = 0,015) y una frecuencia cardiaca inicial menor (FF = 83,3 ± 10,23 PPM vs. FL = 92,9 ± 7,67 PPM; p = 0,034) en la prueba de esfuerzo. Además, Respecto a las habilidades cognitivas, en la fase folicular se obtuvieron mejores resultados en el tiempo de reacción tanto con la mano derecha (FF = 0,426 ± 0,082 s vs. FL = 0,453 ± 0,087 s; p = 0,036) como con la mano izquierda (FF = 0,435 ± 0,096 s vs. FL = 0,466 ± 0,077 s; p = 0,034). Por otro lado, se encontró un mayor porcentaje de grasa (FF = 27,3 ± 5,1% vs. FL = 27,9 ± 5,0%; p = 0,041) en la fase lútea.
Conclusión: El rendimiento en resistencia y en aspectos cognitivos como es el tiempo de reacción fue mejor en la Fase Folicular mientras que se observó un mayor porcentaje de grasa en la Fase Lútea. Sin embargo, la memoria, la fuerza y las características musculares no se vieron afectadas por las fluctuaciones hormonales propias del ciclo menstrual.

Palabras clave:
Ciclo menstrual. Mujer. Aspectos cognitivos. Rendimiento. Actividad física.

Award for the best communication of the Conference of Badajoz

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Introduction

In recent years, the participation of women in sport has increased, creating the need to understand exercise physiology in the female athlete in detail[1]. In the 1980s, it was accepted that physiological responses to exercise did not differ between men and women[2]. With more research, it has been shown in recent decades that in the early stages of childhood there are no differences between the sexes and that discrepancies appear from puberty, coinciding with the beginning of testosterone production in men[3]. In adulthood, men secrete thirty times more testosterone than women, giving them a significant advantage in terms of strength, speed and endurance[4,5].

Women start their menstrual cycle (MC), one of the most important biological rhythms of human physiology, when they reach puberty[6]. It is a physiological process generated by the interaction of the hypothalamus with pituitary hormones, which cause various changes not only in the female reproductive system but also in other body tissues[7]. The ovarian cycle lasts from 25 to 30 days and is divided into two phases according to the ovarian function in each: the follicular phase (FP) and luteal phase (LP)[8]. The follicular phase begins with menstruation, which usually lasts 4 to 6 days[9]. From day 6, the hypothalamus secretes gonadotropin-releasing hormone (GnRH) more frequently to produce follicle-stimulating hormone (FSH) and luteinising hormone (LH)[10]. FSH stimulates the growth of follicles in the ovary and, as a result, drives the production of oestradiol. LH reaches its peak on day 14 of the cycle, causing the release of the mature follicle from the ovary to the fallopian tube, i.e. ovulation[11]. The luteal phase is characterised by the formation of the corpus luteum and the secretion of progesterone[12]. The luteal phase ends with the death of the corpus luteum, causing a decrease in progesterone, and the degradation of the endometrium through menstrual bleeding, bringing the menstrual cycle to an end[13].

There are a variety of mechanisms that suggest that cyclical fluctuations of oestrogen and progesterone during the MC could affect athletic performance. Oestrogens modulate body composition by increasing fat mass[14] and provoking water retention[15]. Interestingly, oestrogens also increase muscle glycogen storage capacity[16], which improves oxidative capacity and decreases dependence on anaerobic pathways for adenosine triphosphate (ATP) production. Therefore, high oestrogen levels are associated with lower blood lactate levels and decreased muscle fatigue[17]. In turn, progesterone influences other parameters, such as resting heart rate, which increases markedly in the luteal phase[18]. As a result, the subjective perception of effort increases, attenuating sports performance[19]. It also promotes protein catabolism, which in turn reduces the stimulation of muscle protein synthesis[20]. Therefore, the increase in oestrogens and a decrease in progesterone which occurs in the follicular phase should be related to greater results in terms of strength and power. Focusing on muscle stiffness, Yim *et al.*[21] suggest that the increase in oestrogens in certain phases of the MC reduces the stiffness of different muscle and connective tissues. In recent years, consideration has been given to the possibility that the menstrual cycle, and specifically progesterone, might have a negative effect on some cognitive skills, such as short-term memory[22] or reaction time, but other studies have concluded that altered perceptions and sociocultural expectations, rather than identifiable cognitive deficits, may play a significant role[23].

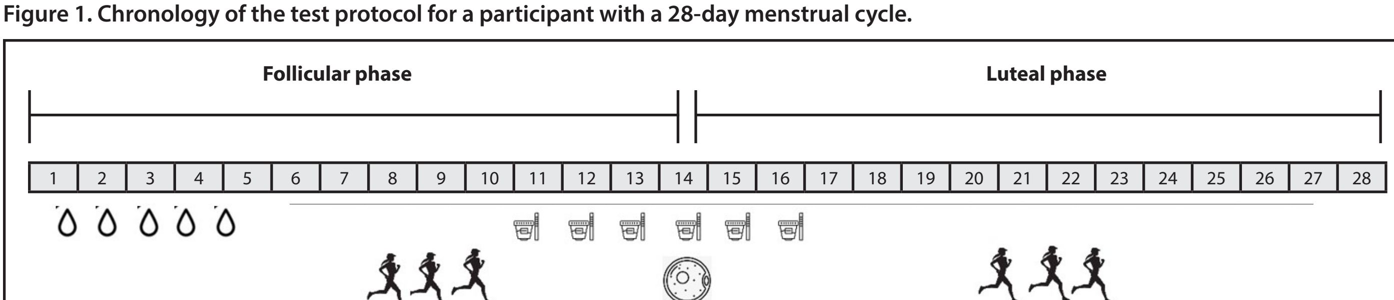
Taking into account the above, it would not be correct to apply studies carried out in men directly to women, given the physiological and endocrinological differences between the sexes[24]. From this evidence, a line of research focused on studying the effects of female physiology was developed[25], concluding that to carry out an ideal study on sports performance in women, the effects of hormonal fluctuations in the menstrual cycle should be taken into consideration. Therefore, the purpose of this study was to evaluate the effect of the menstrual cycle on body composition, resistance, different cognitive aspects (memory and reaction time) and muscle characteristics (muscle strength, thickness and stiffness) in young eumenorrheic women. It was hypothesised that in the luteal phase greater body mass and water percentage would be observed, and that greater physical performance and a better response of cognitive skills such as short-term memory would be seen in the follicular phase.

Material and method

Research design

The experimental design of this study was repeated measures. The dependent variables were measured at two different points in the participants' menstrual cycle, specifically in the middle of the follicular phase and the middle of the luteal phase (Figure 1). According to recent

Figure 1. Chronology of the test protocol for a participant with a 28-day menstrual cycle.



studies, these two moments represent preovulation and peak progesterone concentration, respectively[9]. The start of menstruation was taken as day 1 of the cycle and the middle of the follicular phase between eight and ten days after the first day of menstruation. The middle of the luteal phase was taken as days 20-22 for a regular 28-day cycle. The choice of these moments was made following the methodology in the study by Carmichael *et al.*[9]. First, the participants were familiarised with the protocol one week before the start of the experimental stage in order to minimise any effects related to learning during the measurements. The measurements were taken during two consecutive phases (FP and LP), but in which of the two phases each of the subjects began was randomised in such a way that half of the subjects started with the FP and the other half with the LP. On each measurement day, the tests were performed in the same order: dual-energy X-ray absorptiometry (DXA) and bioimpedance to assess body composition; a reaction time and short-term memory test; an ultrasound to study the thickness of the rectus femoris muscle and a muscle stiffness test on the same muscle; a maximum knee extension and flexion strength test; and finally a stress test (Figure 2).

Participants

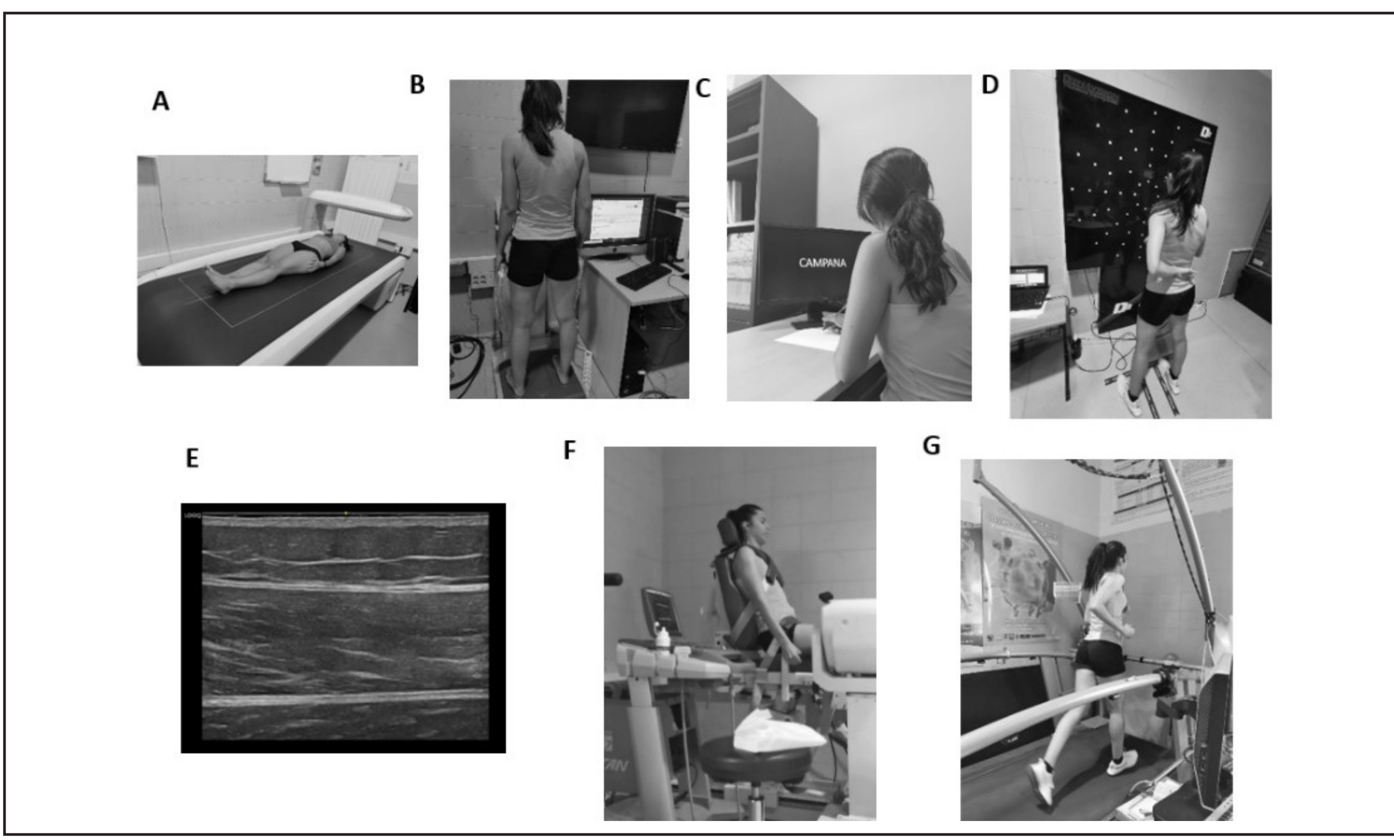
Eight young eumenorrheic women (age = 23.1 ± 4.4 years; total mass = 56.33 ± 6.65 kg; height = 165.5 ± 4.7 cm) with regular menstrual cycles voluntarily participated in the study. The inclusion criteria for all participants were: being of legal age, being physically active (performing physical activity at least three days a week) and the absence of menstrual disorders. The participants had no experience with hormonal contraceptives or supplements for at least 6 months prior to the test and had a history of clinically normal menstrual cycles. Subjects were excluded if they reported any type of injury within the 6 months prior to the start of the study, a positive smoking status, use of oral contraceptives or hormonal supplements, or any type of menstrual disorders, such as dysmenorrhea or amenorrhea, or severe symptoms associated with PMS[26].

Procedure

Determination of the phases of the menstrual cycle

The regularity and duration of the menstrual cycle were monitored in each participant during the 6 months prior to the start of the research

Figure 2. Pictures taken during testing. A. Densitometry test. B. Bioimpedance test. C. Memory Test. D. Reaction Time test. E. Ultrasound of the rectus femoris. F. Isokinetic strength test. G. Stress test.



using a mobile application (Mycalendar®, Period-tracker, USA). With this app, the participants completed a menstrual diary that included: the start and end of bleeding, ovulation day and the total duration of the cycle. The cycle was assessed individually in each subject and the average was 29.3 ± 1.5 days[27]. During the familiarisation tests, they were told that they should measure basal body temperature (BBT) and mass every morning immediately after waking up. Temperature increases of at least 0.3°C, body mass changes of at least 0.5% and the information provided by the period tracking app also helped identify the phases of the menstrual cycle[28]. They were given test strips (Ovulation LH Test Strip; Cuckool. China) to assess the increase in luteinising hormone (LH) in the first morning urine sample and thus determine the day of ovulation. Thanks to all this information, it was possible to determine the times at which the measurements were made, the follicular phase 25-30% and the luteal phase 70-75% of the duration of the individual menstrual cycle. This protocol allowed tests to be performed at the same points in the cycle for all participants, despite differences in the durations of their MC[29] (Figure 1).

Body composition analysis

First, body mass with as little clothing as possible and height were measured using scales with a stadiometer (Seca 711, Seca, Germany). Subsequently, the participants underwent a bone mineral density examination by means of DXA (GE Lunar IDXA, GE Healthcare, Madison, WI, USA), which allowed us to record bone mass, fat percentage and soft tissue composition[30]. The densitometry was performed using the whole body protocol, where the subject lay in supine position with their arms extended alongside their body and their feet together. Body composition analysis was completed with a bioimpedance examination with an InBody 720 (Biospace Inc. Tokyo, Japan), which analysed parameters such as body fat percentage, skeletal muscle mass, total body water and basal metabolic rate. To do this, the patient had to get onto the Inbody, hold the upper handlebars with both hands, placing her thumbs on the specific contacts and holding the position without moving until the instrument finished measuring[31].

Cognitive aspects

First, reaction time was measured using a Dynavision™ D2 Visuomotor Device (Dynavision International LLC, West Chester, OH, USA). This device consists of a board (1.21 m × 1.21 m) containing 64 buttons that serve as visual stimulus. They are arranged in 5 concentric circles around a central screen which should be at eye level. The test was standardised by having the subjects stand 40 cm from the screen with their feet 15 cm apart. The protocol used was the Reaction time protocol developed by Wells *et al.*[32]. The test consisted of pressing the "home" button which was lit up red and, after a new red light lit up on the board, pressing the button to turn off the light as quickly as possible. The protocol was performed three times with each hand and the best time between the button lighting up and the participant pressing it was taken.

The other cognitive variable was short-term memory using a visual test similar to the one developed by Nelson *et al.*[33] to study the modulation of memory storage processes. It consisted of three lists, one for each data collection (familiarisation, FP and LP), containing very specific words with concreteness and imagery ratings of >6.40 on a scale of 1 to 7 from the Paivio *et al.* norms[34]. Each of the 20 words on the list was shown for 5 seconds, the presentation lasting 100 seconds in all. There was then a 100-second consolidation period. After that, the subjects had 120 seconds to write down as many words as they could remember, regardless of the order in which they were shown[35].

Muscle characteristics (strength, thickness and stiffness)

For muscle characteristics, first of all, we studied the thickness of the rectus femoris muscle by ultrasound, using a Logiq® S8 ultrasound (GE Healthcare, Milwaukee, WI, USA). To do this, the participants sat with a knee flexion of 20°, and the midpoint between the anterior superior iliac spine and the upper edge of the patella was marked with a marker pen to locate ourselves on top of the rectus femoris. The distance between the superficial and deep aponeurosis of the rectus femoris was measured perpendicular to the muscle fibres. Subsequently, passive muscle stiffness in a relaxed state was measured using a manual myotonometry device, the MyotonPRO (Myoton AS, Tallinn, Estonia), which applies a brief mechanical pulse for 5 ms to cause damped oscillations. Stiffness was measured at the same location as the earlier ultrasound.

Finally, maximum knee extension and flexion strength were measured with a unilateral isometric test, measuring the dominant leg with Biodex System 3 (Biodex Medical Systems; Shirley, NY, USA). Prior to this test, the participants warmed up for 5 minutes on a cycle ergometer at 50 watts. Then the participants sat in the isokinetic chair with the knee joint flexed at 90°and were secured in position with different straps. Once in the test position, the participants performed several submaximal knee flexion and extension repetitions to complete the warm-up. The protocol used consisted of a maximal knee extension for 5 seconds, 10 seconds of rest, and then 5 seconds of maximal knee flexion. This test was performed 3 times with one minute of rest in between[36].

Resistance

A stress test was performed on an HP Cosmos Saturn Med 4.0 treadmill (Saturn, Traunstein, Germany). The protocol consisted of a two-minute warm-up phase walking on the treadmill at 4 km/h. After one minute of warming up, the participants' heart beats were recorded and taken as initial rate using the Polar H9 heart rate monitor (Polar Electro Oy, Kempele, Finland). After the warm-up, the stress test began. The participants started running at 6 km/h and the speed was increased by one km/h each minute, At the end of the stress stage, the total time, maximum speed achieved and final heart rate were recorded. To finish the test, the participants recovered by walking at 4 km/h for 3 minutes. Their heart rate was recorded at the end of the first minute of recovery.

Statistical analysis

The software used for statistical analysis was: a Microsoft Excel spreadsheet (Microsoft, Redmond, WA, USA) for storing measurement data and SPSS v. 22.0 (SPSS Inc., Chicago, IL, USA) to perform statistical calculations. The normality of the variables was initially checked with the Shapiro-Wilk test. As all variables showed a normal distribution, Student's t-test was used for related samples to analyse the differences between the two time points in the cycle analysed (FP vs. LP). The relationships between variables were analysed with the Pearson correlation coefficient. The effect sizes for all pairwise comparisons were calculated using the d-Cohen test. The magnitude of the effect size was interpreted using the scale proposed by Cohen: An effect size (ES) of 0.2 was considered small, around 0.5 was considered medium, and around 0.8 was considered large. $P<0.05$ was taken as the significance level.

Results

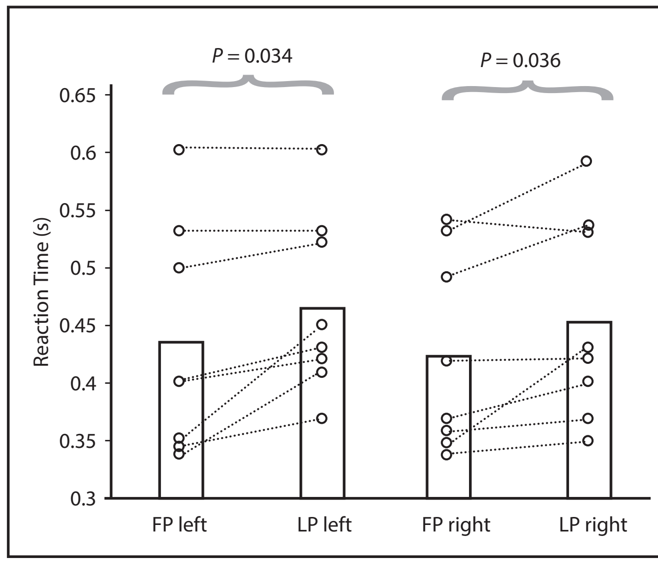
The data for the body composition variables are shown in Table 1. An increase ($P<0.05$) of total fat and fat percentage was found in the luteal phase compared with the follicular phase. On the other hand, no significant differences were found in total mass, BMD or skeletal muscle mass between the two phases analysed (Table 1).

No significant differences were observed during the phases of the menstrual cycle in terms of short-term memory (FP = 15.5 ± 3.9 words vs. LP = 14.7 ± 3.1 words; $P = 0.468$; 95% confidence interval (CI): -1.6 to 3.1 words; ES = 0.1). However, an improvement in reaction time was observed in the follicular phase, both with the right hand (FP = 0.426 ± 0.082 s vs. LP = 0.453 ± 0.087 s; $P = 0.036$; 95% CI: -0.050 to -0.002 s; ES = 0.9) and the left hand (FP = 0.435 ± 0.096 s vs. LP = 0.466 ± 0.077 s; $P = 0.034$; 95% CI: -0.059 to -0.003 s; ES = 0.9) (Figure 3).

No significant differences were found when comparing the two phases of the menstrual cycle in terms of rectus femoris morphology and stiffness or maximal knee extension and flexion strength (Table 2).

Regarding resistance, we found a higher heart rate before starting the test in the luteal phase compared with the follicular phase (FP = 83.3 ± 10.2 beats/min vs. LP = 92.9 ± 7.7 beats/min; $P = 0.034$; 95% CI: from -10.0 to -1.2 beats/min; ES = 0.8). However, participants lasted longer in

Figure 3. Right and left hand reaction time in the Dynavision™ Reaction Time test.



FP: follicular phase; LP: luteal phase.

Table 1. Effects of the menstrual cycle on body composition.

	Follicular phase	Luteal phase	Δ	p-value	95% CI	ES
Total mass (kg)	54.4 ± 7.7	55.0 ± 7.9	-1.1	0.349	-2.3 to 0.2	0.4
BMD (g/cm²)	1.13 ± 0.14	1.14 ± 0.13	-0.9	0.554	-0.08 to 0.01	0.4
Fat percentage (%)	27.3 ± 5.1	27.9 ± 5	-2.2	0.041	-0.6 to -0.3	0.7
Total fat (g)	14.9 ± 4.2	15.4 ± 4.4	-3.4	0.036	-0.45 to -0.04	0.7
Skeletal muscle mass (kg)	23.54 ± 3.23	23.49 ± 3.42	0.2	0.695	-0.2 to 0.3	0.1

ES: effect size; CI: confidence interval; BMD: bone mineral density.

Table 2. Effects of the menstrual cycle on muscle characteristics.

	Follicular phase	Luteal phase	Δ	p-value	95% CI	ES
Rectus femoris thickness (mm)	1.53 ± 0.37	1.58 ± 0.19	-3.3	0.515	-0.22 to 0.12	0.2
Stiffness (N/m)	197.43 ± 15.83	193.43 ± 15.54	2.0	0.300	-4.64 to 12.64	0.4
Maximal extension strength (N)	174.1 ± 58.5	168.4 ± 47.6	3.3	0.589	-18.15 to 29.58	0.2
Maximal flexion strength (N/m)	73.3 ± 9.8	80.4 ± 22.8	-9.7	0.742	-33.5 to 10.1	0.2

ES: effect size; CI: confidence interval.

the test in the follicular phase (FP = 488.5 ± 93.2 s vs. LP = 468.6 ± 81.3 s; *P* = 0.029; 95% CI: from 2.7 to 37.1 s; ES = 0.9). We found no difference in heart rate at the end of the test (189.1 ± 8.8 beats/min vs. 189.5 ± 10.8 beats/min; *P* = 0.807; 95% CI: from -3.8 to 3.1 beats/min; ES = 0.1) or after one minute of recovery (170.1 ± 11.9 beats/min vs. 171.8 ± 11.2 beats/min; *P* = 0.650; CI 95%: from -9.7 to 6.5 beats/min; ES = 0.2).

Discussion

The purpose of this study was to examine the effect of the menstrual cycle on body composition, resistance, different cognitive aspects (memory and reaction time) and muscle characteristics (muscle strength, thickness and stiffness) in young eumenorrheic women. The most important findings of the study were: 1) Total body fat and fat percentage were higher in the luteal phase, 2) In resistance, a longer total exertion time and a lower basal heart rate in the follicular phase, 3) Reaction time was better in the follicular phase and, finally, 4) Short-term memory, muscle strength and muscle characteristics were not affected by the menstrual cycle and the hormones involved.

Analysis of the body composition variables throughout the menstrual cycle showed higher values in total fat mass and fat percentage in the LP. These variations in total fat could be one of the causes of variations in sports performance in women. Many women claim to experience physical changes during the menstrual cycle, highlighting weight gain, notably in the luteal phase in the days prior to menstrual flow[14]. Carmichael *et al.*[9] found higher fat mass in DXA analysis in the LP in comparison with the FP. They controlled the subjects' diet for 24 hours and carried out a hydration analysis beforehand in order to eliminate any variables that could influence the results. In our study, we did not find significant differences in body water, although it should be taken into account that we did not control the degree of hydration of the subjects. The participants were asked, however, to come to the laboratory on the two days in the same preceding conditions and all the participants carried out both tests at the same time of the day. It is understandable that BMD does not change at different points in the menstrual cycle because it is a parameter that varies very little over time[6].

Regarding resistance, the total time of the stress test shows results similar to those recorded in recent research which concludes that responses to submaximal exercise are significantly different during the phases of the menstrual cycle[19]. Some studies suggest a possible slight increase in aerobic capacity or exercise efficiency during the follicular phase[6]. These claims may be related to the high oestrogen levels characteristic of the follicular phase and their relationship with low lactate levels[17]. An inverse relationship has been observed where higher oestrogen levels correspond to lower lactate levels, resulting in decreased muscle fatigue and thus improved performance. In this study, we recorded a higher initial heart rate in the luteal phase, which may be related to the high levels of progesterone which are typical of it[18]. Nevertheless, plenty of studies do not confirm this hypothesis and argue that there are no differences in aerobic and anaerobic capacity over the course of the menstrual cycle[6].

Henderson[22] studied the effect of progesterone on women's cognitive performance and observed that the difference was minimal in women of reproductive age but that progesterone had a detrimental effect on short-term memory after menopause and hormone therapy. In our study, we found no differences between the two phases analysed in terms of short-term memory, in line with recent studies that, similarly, have not observed any clinically significant important and consistent effects of progesterone on cognitive function in women[37].

Regarding reaction time, we found significant differences in both the right and the left hand, with participants in the follicular phase showing better reaction times. Although Karia[38] concluded that reaction time is a skill that depends on a wide variety of factors such as age, sex and the number, intensity and duration of the stimuli, other studies have found relationships between fluctuating oestrogen and progesterone levels during the normal menstrual cycle and reaction time[39]. Kumar *et al.*[40] attributed the prolongation of reaction time in women during the luteal phase to the female sex hormones, which cause salt and water retention, which in turn influence the process of axonal conduction and availability of neurotransmitters at the synapse. Morgan and Rapkin[23] have shown a positive correlation between reaction time and body mass index in women: the greater the body mass, the longer the reaction time.

The variables related to muscle strength analysed in this study remain constant over the phases of the menstrual cycle despite the fluctuations in concentrations of circulating levels of oestrogen and progesterone that occur during them[41]. This can be seen in different studies where eumenorrheic women who participate in sports or activities that depend on strength seem not to be disadvantaged by the menstrual phase they are in[29]. However, the comparison of results is difficult due to the lack of research with strength measurements similar to those taken in this study and the use of different methodologies to determine the phases of the menstrual cycle. The study by Birch and Reilly[42] in which they analysed the isometric strength of the lower limb muscles in FP and LP concluded that the production of maximal voluntary force did not appear to be influenced by menstrual phases. Muscle strength, power and speed were not affected either. Although the results point to no significant differences in the mechanical variables, we know that hormonal fluctuations during the menstrual cycle are indisputable and these should be controlled for clearer results. Some studies where serological tests were performed to control hormone levels observed that muscle strength changed, proving to be greater in the follicular phase[43]. These results support the idea that skeletal muscle is sensitive to changes in oestrogen concentration and should be taken into account when planning training and developing strategies to prevent injuries to the lower extremities during sports activities[43].

Study limitations

There were several limitations in this study which should be acknowledged. First, the sample size was small, so the results should be treated with caution. Consequently, finding significant relationships between the variables analysed is complex because statistical tests require a certain sample size to ensure representativeness. It is also important to highlight the problems associated with the precise identification of the menstrual phases in each participant. Although false-positives are highly unlikely in urine LH tests, the tests depended on participants performing them correctly. To minimise the bias produced by self-measurement, the participants received precise indications prior to measuring. Despite these limitations, the study provides some indications on the effects of the phases of the menstrual cycle on the physical and cognitive abilities of eumenorrheic women.

Conclusions

We can conclude that body composition, reaction time and resistance test performance are different in the phases of the menstrual cycle analysed (luteal phase and follicular phase). In the luteal phase, a higher fat percentage and more total fat are found than in the follicular phase, while performance in reaction time and the resistance test is better in the follicular phase. On the other hand, short-term memory, muscle thickness and stiffness, and strength are not been affected by the hormonal changes that occur during the menstrual cycle.

Conflict of interest

The authors declare that they are not subject to any type of conflict of interest.

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