Apunts Med Esport. 2019;54(202):65–72

apunts
MEDICINA DE L'ESPORT
www.apunts/org

ORIGINAL ARTICLE

Is there a difference toward strength, muscular endurance, anaerobic power and hormonal changes between the three phase of the menstrual cycle of active girls?

Hamid Arazi[a,*], **Sabikeh Nasiri**[b], **Ehsan Eghbali**[a]

[a] *Department of Exercise Physiology, Faculty of Sport Sciences, University of Guilan, Rasht, Iran*
[b] *Department of Exercise Physiology, Islamic Azad University, Rasht Branch, Rasht, Iran*

Received 5 September 2018; accepted 5 November 2018
Available online 14 December 2018

KEYWORDS
Menstrual cycle;
Muscular strength;
Muscular endurance;
Anaerobic power;
Hormonal changes

Abstract
Background: Menstrual cycles are affected by the concentration of estrogen and progesterone hormones affecting the individual's functional and physical factors.
Aims: The purpose of this study was to investigate the difference (and relationship) toward strength, muscular endurance, anaerobic power and hormonal changes between the three (follicular, ovulation, luteal) phases of the menstrual cycle of active young girls.
Methods: Twenty young girls were selected randomly and purposefully in the age group from 20 to 30. Hormonal changes in follicle-stimulating hormone (FSH), luteinizing hormone (LH), one repetition maximum (1RM or strength) of upper body and lower body, and muscular endurance test with 60% 1RM of upper body and lower body in the three phases of the menstrual cycle were measured. Also, running-based anaerobic sprint test (RAST) was used to estimate anaerobic power.
Results: The results of this study showed that there was no significant difference between muscular strength and endurance in the three phases of the menstrual cycle (upper and lower body muscle strength: $P = 0.13$, $P = 0.23$; muscular endurance: $P = 0.33$, $P = 0.5$, respectively). Also, the results indicated no significant difference in anaerobic power in the three phases of the menstrual cycle ($P = 0.45$). In contrast, there was a significant difference between LH and FSH levels in the menstrual cycle phases ($P = 0.001$).
Conclusions: The different phases of the menstrual cycle practically do not limit the physical and physiological performance of active young girls, and girls can participate in sports activities without worrying about a drop in performance.

* Corresponding author.
E-mail address: hamidarazi@yahoo.com (H. Arazi).

https://doi.org/10.1016/j.apunts.2018.11.001
1886-6581/

PALABRAS CLAVE
Ciclo menstrual;
Fuerza muscular;
Resistencia muscular;
Potencia anaeróbica;
Cambios hormonales

¿Existe diferencia entre fuerza y resistencia muscular, potencia anaeróbica y cambios hormonales entre las tres fases del ciclo menstrual de las jóvenes activas?

Resumen

Antecedentes: Los ciclos menstruales son afectados por la concentración de estrógeno y progesterona, que afectan a los factores funcional y físico del individuo.

Objetivo: El objetivo de este estudio fue investigar la diferencia (y relación) entre fuerza y resistencia muscular, potencia anaeróbica y cambios hormonales entre las tres fases (folicular, ovulación, lútea) del ciclo menstrual de las jóvenes activas.

Métodos: Se seleccionaron veinte chicas intencionada y aleatoriamente del grupo de edad comprendido entre 20 y 30 años. Se midieron los cambios hormonales de la hormona folículo-estimulante (FSH), la hormona luteinizante (LH), una repetición máxima (1RM o fuerza) del tren superior y el tren inferior, y la prueba de resistencia muscular con un 60% de 1RM del tren superior y el tren inferior en las tres fases del ciclo. Se utilizó también la prueba de carrera anaeróbica en *sprint* (RAST) para calcular la potencia anaeróbica.

Resultados: Los resultados de este estudio reflejaron que no existía diferencia significativa entre fuerza y resistencia muscular en las tres fases del ciclo menstrual (fuerza muscular de los trenes superior e inferior: $p = 0,13$, $p = 0,23$, y resistencia muscular: $p = 0,33$, $p = 0,5$, respectivamente). Los resultados indicaron también que no existía diferencia significativa en cuanto a potencia anaeróbica en las tres fases del ciclo menstrual ($p = 0,45$). Por contra, existía una diferencia significativa entre los niveles de LH y FSH en las fases del ciclo menstrual ($p = 0,001$).

Conclusiones: Las diferentes fases del ciclo menstrual no limitan prácticamente el desempeño físico y fisiológico de las jóvenes activas, pudiendo participar las chicas en actividades deportivas sin preocuparse acerca de la caída de rendimiento.

Introduction

Increasing participation of women in sport has increased the interest in physiological and metabolic responses of women to exercise.[1] In the last decade, studies have been conducted to understand the relationship between physical activity and menstrual cycle often focusing on the mechanism of hormones involved in menstruation. At each stage of the menstrual cycle, hormonal changes and different physiology occur in the body of athlete women affecting their working capacity; awareness of the women physiological ability has an irrefutable significance in understanding the interactions between physical activity and various phases of the menstrual cycle.[1]

The menstrual cycle can affect performance. Hormonal disorders during the menstrual cycle can cause changes in muscle strength, endurance, and metabolism.[2] Many biological factors, such as menstrual cycles, use of contraceptive pills, physical fitness, nutritional status, and stress can affect the interaction between physical training and hormonal responses.[3] Some physiological factors and athletes performance may vary throughout the menstrual cycle. The changes seen in these physiological characteristics in various systems are related to hormonal levels fluctuations affecting the neuromuscular system and metabolic function of the body.[4]

One of the most important and controversial issues in this regard is how interactions between different phases of the menstrual period affect some hormones and physiological capabilities such as strength, muscular endurance, and anaerobic power. At each stage of the menstrual cycle, hormonal and different physiological changes occur in the body of women affecting their physical working capacity. Every month, from the onset of the first menstruation until the menopause, one of the two ovaries produces an ovum that is released into the abdominal cavity during ovulation and transported to the uterus. If ovum is not fertilized, the endometrium breaks down and is excreted with ovum in the menstrual flow within 3–5 days.[2] The mean duration of each period is 28 days, which can vary between 20 and 45 days in normal women. The ovaries are stimulated by the anterior pituitary gonadotropic hormones, which are FSH and LH. The ovaries also secrete estrogen and progesterone hormones. In each sex, there is a periodic increase and decrease in secretion of this hormones.[2] During a normal menstrual period, women are subject to constant changes in sex steroid hormones. Estrogen begins to increase in the middle of the follicular phase reaching its peak before ovulation. Estrogen and progesterone increase in the middle of the luteal phase causing extensive physiological effects.[5] Throughout the cycle, reproductive performance in women is controlled by the hypothalamus–pituitary axis and as a result of large and predictable fluctuations in estradiol and progesterone. Sex steroid hormones can affect the central nervous system at the plasma level, which is because steroids can easily pass through the blood–brain barrier because of high fat solubility.[6]

At each stage of the menstrual cycle, there are potential and hidden changes in the level of sex hormones such as estrogen, as well as different physiological changes in the body of women affecting their physical working capacity. Some researchers have argued that increasing estrogen accelerates the function of respiratory nerves. From the past, many studies have been carried out on the effects of various biological conditions on the various sports activities and vice versa. One of these biological factors is the three menstrual cycles phase in women. In the past, they believed that hard exercises were not useful to women and did not affect their physical strength. However, many investigations have violated this theory[7] and the cause of women increased power is due to increased ability to strengthen and coordinate movements. Most women are advised to restrict or stop their sport activities during menstrual cycle. These recommendations are more serious about endurance and strength exercises and important competitions, and generally encourage women to do the least exercise during menstrual cycle. Various theories have been presented to explain the relationship between different types of athletic and menstrual cycles. Some argue that increasing or decreasing certain hormones may affect strength and endurance.[1] However, these theories or other theories are not explicitly approved and there are ambiguities around them. In some studies, it has been shown that a group of weight lifters women had a weaker performance before menstruation, while they showed better records at menstruation. Also, they achieved better results at post menstruation.[1]

During the year, the level of production of female hormones varies according to the menstrual cycle. The four hormonal markers of the menstrual cycle (estrogen, progesterone, FSH and LH) exhibit constant changes throughout the cycle. These female steroid hormones affect the automatic nervous system and metabolism. Therefore, physiological behaviors along with menstrual cycles can affect the performance parameters of the sport activities.[8] However, the effect of the phases of the menstrual cycle on physical function, especially muscular strength and muscular endurance is unknown. In some studies, the effects of menstrual cycles on athletic exercise are vague. Focusing on studies, the use of hormonal effects and electrical stimulation to ensure maximal neuronal activation show that the fluctuations of female sex hormones throughout the menstrual cycle do not affect the contraction of muscle. However, the menstrual cycle may have an effect on anaerobic exercise performance, endurance, and muscle strength. However, research are lacking to prove these theories (the ineffectiveness of exercise with menstrual cycle or the effectiveness of physical activity with the menstrual cycle) and limited studies have investigated the ineffectiveness of several physical factors and menstruation ages not ending in a clear and conclusive result. Therefore, it seems that an examination of the ambiguities in this field can be helpful in solving questions about women time of activities and competition. Accordingly, we will attempt to compare the difference and relationship between strength, endurance, anaerobic power and hormonal changes (FSH, LH) with the triple (follicular, ovulation, luteal) phase of the menstrual cycle of active young girls.

Methods

Participants and study design

Twenty recreationally trained females (26.27 ± 2.75 years) participated in this study. Females were included as the study participants who had normal periods for more than six months without a history of use of oral contraceptives and hormones, smoking, gravidity and parity, hypertension, cardiovascular disease, exercise habits, and irregular menstrual cycle. The participants were instructed to refrain from consuming any caffeine-containing drinks for 24 h prior to the study, and were also asked to avoid strenuous physical activity or intense exercise for 24 h before participating in the study. Setting the days of each test was based on the history of menstruation. Research tests were performed on days 3–8 of the follicular phase, between 12 and 14 days of ovulation and 18–25 in the luteal phase of the menstrual cycle of the girls. The subjects participated in three steps for the measurements.

On the day of the survey, all participants were fully informed about the content and procedures of the research and consented to the participation. They were asked to complete the health history questionnaire, and were fully informed about the items, steps and cautions of the survey.

Additionally, the body density was determined by calculating the body fat percentage using the Jackson and Pollack method[9] (subcutaneous fat thickness of the three points of the body including the triceps of the arm, abdomen and super iliac). Then, the percentage of body fat was calculated using the Brozek equation.[10] The skin thickness was obtained by Lafayette calibrated caliber (Lafayette model 01127, USA) with a precision of 1 mm. All measurements were performed from the right side of the body with three repetitions, and the average of two digits close to each other was recorded as the final figure.

Anthropometric and physical fitness measurements in the exercise room and blood sampling were carried out at pathobiology lab. After reaching 12 h of fasting, adequate sleep and severe physical inactivity in the last 2 days, the subjects were present for the 3 steps of blood sampling. Subjects were urged to maintain their usual diet, and this was controlled through a 3-day feeding report.

The anthropometric indices, height and weight were measured using an anthropometric coupled with a WPT 200 OC verified medical scale. BMI (kg/m^2 (was calculated as body weight divided by squared body height. The participants were dressed in minimal clothing during the measurements, which were rounded to the nearest 0.5 kg and 0.5 cm. The study was conducted in accordance with the Declaration of Helsinki and in accordance with the Institutional Ethics Review Committee from the University.

Testing procedures

Anaerobic power

Anaerobic power was measured with RAST test, which consisted of 6 repetitions at a distance of 35 m and the maximum intensity is a quick run with 10 s rest between each repetition (during the test was recorded by the timer carefully 0.01 s) and was calculated using the following formula[11]:

$$\text{Peak anaerobic power} = \text{weight (kg)} \times 35^2 \times \text{repeated fastest time}^3$$

Muscle strength

Test to measure the strength of one repetition maximum in the bench press and leg press exercises were used. One repetition maximum in the bench press and leg press, the maximum amount of weight that subjects can move it once and was calculated using the formula[12]:

$$1\text{RM} = \frac{\text{load}}{(1.0278 - 0.0278\,(\text{number of repetition to exhaustion}))}$$

Muscular endurance

Muscular endurance test with 60% 1RM in the bench press and leg press exercises, were performed as follows: first, 60% 1RM (strength) was obtained in the above exercises. Participants with determined load as much fatigue performed movement, then repetitions were recorded.

Hormone assays

5 mL of blood samples of each subject were collected in a 12-h fasting state of the venous vein and kept at −20 °C until the test. Blood samples were taken at each of the 3 phase follicular, ovulation and luteal phase at 8–9 o'clock by laboratory technician. Levels of FSH, LH were measured by ELISA kit (company's Pishtaz teb). For FSH, Sensitivity: 1 IU/L, inter-assay CV was less 9.5% and intra-assay was 6.6%; for LH, Sensitivity: 1 IU/L, inter-assay CV was less 6.9% and intra-assay was 4.4%.

Statistical analysis

Descriptive statistics were used to determine the properties of the indicators mean and standard deviation of the participants in terms of age, height, weight, etc. the SPSS version 20 was used for statistical analysis. After ensuring a normal distribution using the Shapiro–Wilk test, analysis of variance (ANOVA) for repeated measures was performed for all comparisons. When the *F*-ratio was significant, LSD post hoc test was employed to identify where mean differences existed. Pearson correlation coefficient was used to determine the association between mentioned variables. The significance level was considered $P \le 0.05$ at all stages.

Results

Participants characteristic that completed the study are shown in Table 1. The results of ANOVA suggested that no difference were found between leg press and bench press 1RM in three phases ($F = 3.27$, $P = 0.23$; $F = 1.96$, $P = 0.13$, respectively). It was also demonstrated that muscular endurance of legs and chest had no significant difference ($F = 0.64$, $P = 0.50$; $F = 1.36$, $P = 0.33$, respectively). There was no significant difference for anaerobic power in three phases ($F = 1.36$, $P = 0.45$). However, Significant differences were observed in LH and FSH levels in three phases ($F = 57.76$, $P = 0.001$; $F = 258.23$, $P = 0.001$, respectively, Table 3).

The results of LSD test showed that changes were significant in LH and FSH levels between follicular phases with ovulation, follicular with luteal and ovulation with luteal ($P \le 0.05$, Fig. 1).

The results of Pearson correlation coefficient indicated no independent association between the leg press and bench press strength and muscular endurance in three phases (follicular-ovulation: $r = 0.31$, $P = 0.55$; follicular-luteal: $r = -0.44$, $P = 0.42$; ovulation-luteal: $r = 0.18$, $P = 0.63$, for muscular strength leg press; follicular-ovulation: $r = 0.10$, $P = 0.79$; follicular-luteal: $r = -0.39$, $P = 0.29$; ovulation-luteal: $r = 0.17$, $P = 0.09$, for muscular strength bench press; follicular-ovulation: $r = 0.23$, $P = 0.55$; follicular-luteal: $r = -0.10$, $P = 0.42$; ovulation-luteal: $r = 0.16$, $P = 0.63$,

Table 1 Participants characteristics (mean ± SD).

Variable	Mean ± SD
Age (year)	26.27 ± 2.75
Weight (kg)	60.14 ± 7.60
Height (cm)	161.00 ± 4.25
BMI (kg/m²)	22.14 ± 2.44
Fat (%)	28.82 ± 5.26
1RM leg press (kg)	
Follicular	75 ± 3.25
Ovulation	72 ± 5.72
Luteal	74 ± 4.66
Luteal	33 ± 6.11
60%1RM leg press (repetition)	
Follicular	10 ± 1
Ovulation	11 ± 1
Luteal	10 ± 2
60% 1RM bench press (repetition)	
Follicular	9 ± 1
Ovulation	8 ± 2
Luteal	9 ± 1
Anaerobic power (w/kg)	
Follicular	3.99 ± 1.08
Ovulation	3.98 ± 1.05
Luteal	4.44 ± 0.98
LH (ng/mg)	
Follicular	6.73 ± 2.25
Ovulation	32.35 ± 9.72
Luteal	3.62 ± 1.66
FSH (ng/mg)	
Follicular	9.68 ± 3.12
Ovulation	15.36 ± 5.59
Luteal	3.89 ± 2.01

BMI = body mass index, 1RM = 1 repetition maximum, LH = luteinizing hormone, FSH = follicle stimulating hormone.

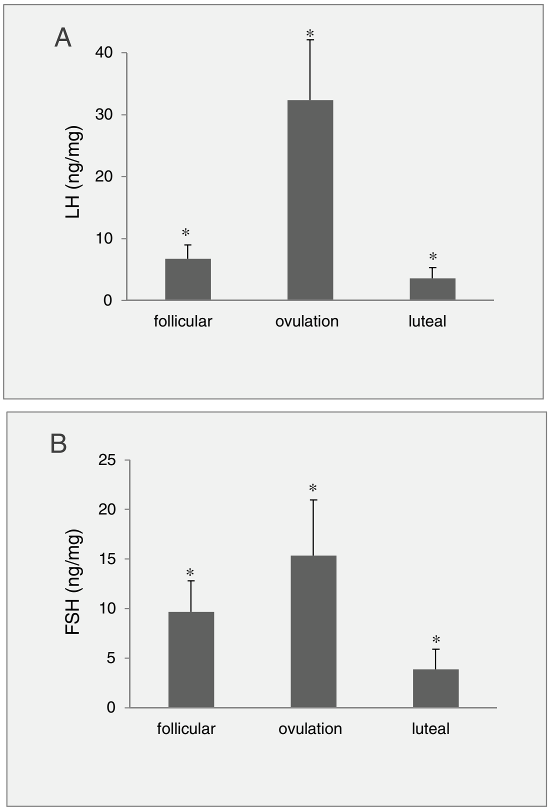

Figure 1 Mean data (±SD) for LH (A) and FSH (B) in the three phase (follicular, ovulation, luteal) of menstrual cycle. *$P \leq 0.05$ between groups.

for muscular endurance leg press; follicular-ovulation: $r = 0.23$, $P = 0.79$; follicular-luteal: $r = -0.12$, $P = 0.69$; ovulation-luteal: $r = 0.18$, $P = 0.19$, for muscular endurance bench press, Table 2). Also, there was no independent association in anaerobic power between follicular with ovulation and follicular with luteal phases ($r = 0.29$, $P = 0.48$; $r = 0.18$, $P = 0.65$, respectively). To the contrary, significant relationship was observed in anaerobic power between ovulation with luteal phase ($r = 0.78$, $P = 0.03$). The results indicated that there was no association in the LH between follicular with ovulation phases, follicular with luteal phase, ovulation with luteal phases ($r = 0.27$, $P = 0.48$; $r = -0.20$, $P = 0.39$; $r = -0.10$, $P = 0.67$, respectively). Also, no association in FSH between follicular with ovulation phases, ovulation with luteal phases ($r = -0.06$, $P = 0.80$; $r = 0.15$, $P = 0.51$, respectively). Nevertheless, the results indicated a moderate and significant negative relationship in the FSH between follicular with luteal phases ($r = -0.48$, $P = 0.03$, Table 2).

Table 2 Relationship between strength, muscular endurance, anaerobic power and hormonal changes with the three phase (follicular, ovulation, luteal) of menstrual cycle.

Variable	*r*	*P*
1RM leg press (kg)		
Follicular-ovulation	0.31	0.55
Follicular-luteal	−0.44	0.42
Ovulation-luteal	0.18	0.63
1RM bench press (kg)		
Follicular-ovulation	0.10	0.79
Follicular-luteal	−0.39	0.29
Ovulation-luteal	0.17	0.09
60%1RM leg press (repetition)		
Follicular-ovulation	0.23	0.55
Follicular-luteal	−0.10	0.42
Ovulation-luteal	0.16	0.63
60% 1RM bench press (repetition)		
Follicular-ovulation	0.23	0.79
Follicular-luteal	−0.12	0.69
Ovulation-luteal	0.18	0.19
Anaerobic power (w/kg)		
Follicular-ovulation	0.29	0.48
Follicular-luteal	0.18	0.65
Ovulation-luteal	0.78	**0.03***
LH (ng/mg)		
Follicular-ovulation	0.27	0.48
Follicular-luteal	−0.20	0.39
Ovulation-luteal	−0.10	0.67
FSH (ng/mg)		
Follicular-ovulation	−0.06	0.80
Follicular-luteal	−0.48	**0.03***
Ovulation-luteal	0.15	0.51

1RM = 1 repetition maximum, LH = luteinizing hormone, FSH = follicle stimulating hormone.
* Significance at the ≤0.05 level.

Table 3 Results of one-way Anova.

Variable	DF	*F*	*P*
1RM leg press	3	3.27	0.23
1RM bench press	3	1.96	0.13
60%1RM leg press	3	0.64	0.5
60% 1RM bench press	3	1.36	0.33
Anaerobic power	3	1.36	0.45
LH	3	57.76	**0.001***
FSH	3	258.23	**0.001***

1RM = 1 repetition maximum, LH = luteinizing hormone, FSH = follicle stimulating hormone.
* Significance at the ≤0.05 level.

Discussion

The purpose of this study was to investigate and compare the relationship between strength, muscular endurance, anaerobic power and hormonal changes with three phase (follicular, ovulation, luteal) in menstrual cycle of active young girls. The results of the study showed that there was no significant difference between strength, endurance and anaerobic power in the three phases of menstruation. In contrast, there was a significant difference between the levels of LH and FSH in follicular, ovulation and luteal phase.

The menstrual cycle can be divided into three phase, separated by estrogen and progesterone ratios: in the follicular phase, there is low estrogen and progesterone, in the ovulation phase, estrogen is high and progesterone is low, and in the luteal phase, estrogen and progesterone levels are high.[13] Estrogen appears to enhance carbohydrate tolerance through its effect on lipolytic enzymes and glucose regulating hormones such as growth hormone, catecholamines and insulin, but progesterone has a counterproductive effect.[13]

The results of this study indicated that there was no significant difference between strength and muscular endurance in different phase of menstrual cycle. In this regard, Vaiksaar et al.[14] indicated that endurance activities were not affected by the natural phase of the normal cycle. Most studies have examined the effect of endurance training on blood androgen concentration. It has been observed that plasma concentrations of total testosterone, free testosterone and androstenedione increased after long term endurance exercises under laboratory and environmental conditions.[15,16] Recently, a study investigated the effect of long-term training on young women with a different hormonal status (age range from 18 to 30 years) including eumenorrheic women and women using oral contraceptives. Their results indicated that there was no significant change in exercise activity in relation to the menstrual cycle.[17] Also, the research conducted by Vaiksaar et al.[18] on women showed that the menstrual cycle steps have no effect on the oxidation of the substrate and the concentration of lactate during rowing exercises with 70% VO2max. In their study, they found that there was no difference in the maximum power between the luteal and follicular phases, and female athletes should not be concerned about their menstrual cycles and its impact on exercise. Does not seem, muscle strength to have a significant fluctuation during the ovulation phase of the cycle.[13] Investigations have shown that there was no significant change in the strength of quadriceps muscle in three phases of menstrual cycle and there was no significant relationship between strength indices and the concentration of female reproductive hormones.[13] Also, Sunaga et al.[19] concluded that changes in female hormones in the menstrual cycle had no effect on the muscle strength and hypertrophy. The results of Bennal et al.[20] showed that there was no significant change in the maximum voluntary contraction of handgrip strength during different phases of the menstrual cycle.

Contrary to these findings, some studies have shown better performance in some phase of the menstrual cycle. The results of research by Julian et al.[21] showed that endurance function decreases in the middle of the luteal phase. In addition, researchers have argued that estrogen may improve endurance activities by altering the metabolism of carbohydrates and lipids with progesterone antagonistic action.[22] Pallavi et al.[4] concluded that cyclic changes in endogenous sex hormones increase muscle strength in the follicular phase of the menstrual cycle. Therefore, these hormones seem to adjust these parameters in the age group before menopause. Also, Sung et al.[23] showed that strength training based follicular phase had a greater effect on muscle strength, diameter of muscle fibers of type II and nuclei-to-fiber ratio in comparison with the strength training based on luteal phase in untrained and moderately trained women. Marília et al.[24] showed that women had a significant reduction in the maximum ratio of hamstring muscle strength to quadriceps during the follicular phase compared to the luteal phase. Also, Tenan et al.[25] showed a reduction in maximum knee extensors strength in the middle of the luteal phase. Tenan et al.[26,27] concluded that the reduction of MVC (maximal voluntary contraction) in the luteal phase may be due to the effects of neuroinhibitory progesterone in the motor cortex and the effect of the menstrual cycle on both engines and the autonomic nervous systems. The lack of similar results may be due to differences in age, hormonal levels, progesterone levels, progesterone receptor sensitivity, genetic factors, menstrual cycle length, and differences in the counting of days at each stage of the menstrual cycle.

The findings of the present study indicated that there was no significant difference between the anaerobic powers of the subjects in the three phase of the menstrual cycle. In this regard, Tsampoukos et al.[1] investigated the effects of menstrual cycle on speed performance (30 s sprint with 2 min of recovery) and concluded that hormonal changes caused by menstrual cycles were not associated with maximum intensity sprint and metabolic responses due to exercise. Also, Wiecek et al.[28] concluded that hormonal changes in the menstrual cycle had no effect on the anaerobic function, speed start, or the women anaerobic endurance. In the study of Julian et al.[21] there was no difference in speed between different phases of the menstrual cycle at 30 m. They concluded that the sprint times of 5 m, 10 m and 30 m were not affected by the steps of the menstrual cycle. The ineffectiveness of the various phases of the menstrual cycle in speed performance has also been reported in some previous studies.[29] Also, the results of Julia et al.[21] showed that people jumping is not affected by the menstrual cycle.

However, in some studies, it has been shown that the anaerobic power can be different in the menstrual cycle. The results of Somboonwong et al.[30] showed that speed performance along with an increased basal body temperature is improved during luteal phase. In addition, it seems that ovarian hormones may affect the sprint or recovery through effect on strength.

In some studies, it has been claimed that carbohydrate loading and basal metabolism increase in the luteal phase, and at this stage, better performance in physical fitness tests is expected than the other phase of the menstrual cycle. However, due to the fact that tests such as power and strength take a little time, the glycogen storage, however small, is sufficient for this period.[31,32] In other words, the effects of different phase of menstruation on changes in glucose consumption can be seen only when the demand for glucose consumption exceeds the critical level.[31] Therefore, there should be no difference between the different phases of menstrual cycle in the implementation of these activities.

The results of this study indicated a significant difference between the levels of LH and FSH in follicular, ovulation and luteal phase. No research has been done in this regard, but, as stated, hormonal changes in FSH, LH, estrogen and progesterone are constantly changing throughout menstrual cycles. This cycle can be divided into halves. The first half of the menstrual cycle is called follicular phase, and the pituitary hormones, FSH and LH are dominant.[2] The second half is called the luteal phase characterized by an increase in the steroid hormones of the ovary, estrogen and progesterone. The hypothalamic release agent (the gonadotropin releasing factor) stimulates the secretion of follicle stimulating hormone. This material then stimulates the release and growth of the dominant follicle in the ovary. The ovaries secrete 17-boestradiol (17 beta-estradiol) in response to increased levels of FSH and LH in the 24-h peak before ovulation. Increasing estradiol through positive feedback stimulates the hypothalamus–pituitary axis to secrete LH, thereby increasing the mediators of the menstrual cycle during ovulation. After ovulation, the remaining cells in the ovary produce estradiol and progesterone. These hormones act through negative feedback for inhibiting the production of more FSH and LH. If the ovum is not fertilized, then fertilization is malignant and the cycle begins again.[2] In addition, the difference in the half-life of FSH (170 min) and LH (60 min) affects their plasma concentrations, and therefore, their amount varies in different phase of development of sexual maturation and various phase of menstrual cycle.[33]

Conclusion

In summary, the present study showed that muscle strength, muscular endurance and anaerobic power of young women are not different at different phase of the menstrual cycle, but the levels of LH and FSH have varied throughout the different phase. Accordingly, it seems physical activity in different phase of women's menstrual cycle does not have a negative effect on their performance, and young women can continue their sports activities during the menstrual cycle.

Ethical approval

''All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.''

Conflict of interest

Authors declare that they don't have any conflict of interests.

Acknowledgements

We gratefully acknowledge the volunteers involved in this study.

References

1. Tsampoukos A, Peckham EA, James R, Nevill ME. Effect of menstrual cycle phase on sprinting performance. Eur J Appl Physiol. 2010;109:659–67.
2. Dawson EA, Reilly T. Menstrual cycle, exercise and health. Biol Rhythm Res. 2009;40:99–119.
3. O'Leary CB, Lehman C, Koltun K, Smith-Ryan A, Hackney AC. Response of testosterone to prolonged aerobic exercise during different phases of the menstrual cycle. Eur J Appl Physiol. 2013;113:2419–24.
4. Pallavi LC, SoUza UJD, Shivaprakash G. Assessment of musculoskeletal strength and levels of fatigue during different phases of menstrual cycle in young adults. J Clin Diagn Res. 2017;11:CC11.
5. Nakamura Y, Aizawa K. Sex hormones, menstrual cycle and resistance exercise. In: Sex hormones, exercise and women. Cham: Springer; 2017. p. 243–56.
6. Stoffel-Wagner B. Neurosteroid metabolism in the human brain. Eur J Endocrinol. 2001;145:669–79.
7. Farage MA, Neill S, MacLean AB. Physiological changes associated with the menstrual cycle: a review. Obstet Gynecol Surv. 2009;64:58–72.
8. Becker D, Creutzzfeldt OD, Schwibbe M, Wutke W. Changes in physiological EEG and psychological parameters in women during the spontaneous menstrual cycle and following oral contraceptives. Psychoneuro Endocrinol. 1982;7:75–90.
9. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. Br J Nutr. 1978;40:497–504.
10. Brozek J, Grande F, Anderson JT, Keys A. Densitometric analysis of body composition: revision of some quantitative assumptions. Ann NY Acad Sci. 1963;110:113–40.
11. Gwacham N, Wagner DR. Acute effects of a caffeine-taurine energy drink on repeated sprint performance of American college football players. Int J Sport Nutr Exerc Metab. 2012;22:109–16.
12. Brzycki M. Strength testing-predicting a one-rep max from reps-to-fatigue. J Phys Educ Rec Dan. 1993;64:88–90.
13. Constantini NW, Dubnov G, Lebrun CM. The menstrual cycle and sport performance. Clin Sports Med. 2005;24:51–82.
14. Vaiksaar S, Jürimäe J, Mäestu J, Purge P, Kalytka S, Shakhlina L, et al. No effect of menstrual cycle phase and oral contraceptive use on endurance performance in rowers. J Strength Cond Res. 2011;25:1571–8.
15. Copeland J, Consitt L, Tremblay M. Hormonal responses to endurance and resistance exercise in females aged 19–69 years. J Gerontol A Biol Sci Med Sci. 2002;57:158–65.
16. Kochańska-Dziurowicz A, Gawel-Szostek V, Gabryś T, Kmita D. Changes in prolactin and testosterone levels induced by acute physical exertion in young female athletes. Hum Physiol. 2001;27:100–3.
17. Enea C, Boisseau N, Ottavy M, Mulliez J, Millet C, Ingrand I, et al. Effects of menstrual cycle, oral contraception, and training on exercise-induced changes in circulating DHEA-sulphate and testosterone in young women. Eur J Appl Physiol. 2009;106:365.
18. Vaiksaar S, Jürimäe J, Mäestu J, Purge P, Kalytka S, Shakhlina L, et al. No effect of menstrual cycle phase on fuel oxidation during exercise in rowers. Eur J Appl Physiol. 2011;111:1027–34.
19. Sakamaki-Sunaga M, Min S, Kamemoto K, Okamoto T. Effects of menstrual phase-dependent resistance training frequency on muscular hypertrophy and strength. J Strength Cond Res. 2016;30:1727–34.
20. Bennal AS, Chavan V, Taklikar RH, Takalkar A. Muscular performance during different phases of menstrual cycle. Indian J Clin Anatom Physiol. 2016;3:1–3.
21. Julian R, Hecksteden A, Fullagar HH, Meyer T. The effects of menstrual cycle phase on physical performance in female soccer players. PLOS ONE. 2017;12:e0173951.
22. Oosthuyse T, Bosch AN. The effect of the menstrual cycle on exercise metabolism. Sports Med. 2010;40:207–27.
23. Sung E, Han A, Hinrichs T, Vorgerd M, Manchado C, Platen P. Effects of follicular versus luteal phase-based strength training in young women. Springer Plus. 2014;3:668.
24. Dos Santos Andrade M, Mascarin NC, Foster R, de Jármy di Bella ZI, Vancini RL, Barbosa de Lira CA. Is muscular strength balance influenced by menstrual cycle in female soccer players? J Sports Med Phys Fit. 2017;57:859–64.
25. Tenan MS, Hackney AC, Griffin L. Maximal force and tremor changes across the menstrual cycle. Eur J Appl Physiol. 2016;116:153–60.

26. Tenan MS, Peng YL, Hackney AC, Griffin L. Menstrual cycle mediates vastus medialis and vastus medialis oblique muscle activity. Med Sci Sports Exerc. 2013;45:2151–7.
27. Tenan MS, Brothers RM, Tweedell AJ, Hackney AC, Griffin L. Changes in resting heart rate variability across the menstrual cycle. Psycho Physiol. 2014;51:996–1004.
28. Wiecek M, Szymura J, Maciejczyk M, Cempla J, Szygula Z. Effect of sex and menstrual cycle in women on starting speed, anaerobic endurance and muscle power. Acta Physiol Hunga. 2016;103:127–32.
29. Tsampoukos A, Peckham EA, James R, Nevill ME. Effect of menstrual cycle phase on sprinting performance. EurJ Appl Physiol. 2010;109:659–67.
30. Somboonwong J, Chutimakul L, Sanguanrungsirikul S. Core temperature changes and sprint performance of elite female soccer players after a 15-minute warm-up in a hot-humid environment. J Strength Cond Res. 2015;29:262–9.
31. Loureiro S, Dias I, Sales D, Alessi I, Simao R, César Fermino R. Effect of different phases of the menstrual cycle on the performance of muscular strength in 10rm. Rev Bras Med Esporte. 2011;17:22–5.
32. Štefanovský M, Péterová A, Vanderka M, Lengvarský L. Influence of selected phases of the menstrual cycle on performance in Special judo fitness test and Wingate test. Acta Gymnica. 2016;46:136–42.
33. Borer KT. Advanced exercise endocrinology. Hum Kinet. 2013.