The influence of the menstrual cycle on the practice of physical exercise: narrative review

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Summary

Introduction: The menstrual cycle (MC) is the second most important biological rhythm, regulated by the hypothalamic-pituitary-ovarian axis and all the hormones involved in it. In addition to reproductive functions, it is speculated that changes in hormone production during different phases of the menstrual cycle may influence other physiological systems, which may have an impact on women's physical performance. In this way, studying the influences of the menstrual cycle on physical exercises gains importance, since little is said about the organization of strategies and intervention for the performance of physical exercises that take into account the possible impacts and changes caused by the MC.
Objective: To review the influence of MC in the practice of aerobic and resistance exercises.
Material and method: The search for articles was carried out in the databases: PubMed and Google Scholar, from August to September 2021, without restriction on date and type of publication, and all articles in English and Portuguese were considered. The research was based on the phases of the menstrual cycle in eumenorrheic young women, who may or may not be athletes, but without known dysfunctions of the menstrual cycle.
Conclusions: Hormonal fluctuations during MC may not significantly and directly affect the cardiorespiratory or musculoskeletal system during physical exercise, as there is the question of the biological individuality of each woman, as well as the relationship with the self-reported symptoms.

Key words:
Hormones. Menstrual cycle. Physical exercise.

La influencia del ciclo menstrual en la práctica de ejercicio físico: una revisión narrativa

Resumen

Introducción: El ciclo menstrual (CM) es el segundo ritmo biológico más importante, regulado por el eje hipotalámico-pituitario-ovárico y todas las hormonas involucradas en él. Además de las funciones reproductivas, se especula que los cambios en la producción de hormonas durante las diferentes fases del ciclo menstrual pueden influir en otros sistemas fisiológicos, lo que puede tener un impacto en el rendimiento físico de la mujer. De esta forma, el estudio de las influencias del ciclo menstrual sobre los ejercicios físicos cobra importancia, ya que poco se habla de la organización de estrategias e intervención para la realización de ejercicios físicos que tengan en cuenta los posibles impactos y cambios provocados por el CM.
Objetivo: revisar la influencia del CM en la práctica de ejercicios aeróbicos y de resistencia.
Material y método: La búsqueda de artículos se realizó en las bases de datos: PubMed, Scielo y Google Scholar, de agosto a septiembre de 2021, sin restricción de fecha y tipo de publicación, y se consideraron todos los artículos en inglés y portugués. La investigación se basó en las fases del ciclo menstrual en mujeres jóvenes eumenorreicas, que pueden ser deportistas o no, pero sin disfunciones conocidas del ciclo menstrual.
Conclusiones: Las fluctuaciones hormonales durante la CM pueden no afectar significativa y directamente el sistema cardiorrespiratorio o musculoesquelético durante el ejercicio físico, ya que está la cuestión de la individualidad biológica de cada mujer, así como la relación con los síntomas autoreferidos.

Palabras clave:
Hormonas. Ciclo menstrual. Ejercicio físico.

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Introduction

During the menstrual cycle (MC), women are exposed to continuous variations in serum concentrations of various female sex steroid hormones regulated by the hypothalamus-pituitary-ovarian axis. Regular hormonal fluctuations of the four major female sex hormones, estrogen, progesterone, follicle stimulating hormone (FSH) and luteinizing hormone (LH), are essential for regulating ovulatory cycle patterns[1].

Despite individual variations, the MC lasts an average of 28 days comprising two distinct cycles: the ovarian cycle and the endometrial cycle. The ovarian cycle is divided into follicular and luteal phases. In the former, estrogens gradually increase, causing FSH and LH to reach their peak, while progesterone remains low at all time. The luteal phase is determined by the actions of estrogen and progesterone. The endometrial cycle is divided into a proliferative phase, a secretory phase and menstruation. Endometrial growth is the primary outcome of the proliferative phase and it is mediated by the estrogen increase. The primary outcome of the secretory phase is the maturation of the endometrium. Decreasing levels of estrogens halt endometrial lining growth. When conception does not occur, the endometrial lining is replaced to prepare for the next cycle, therefore the ovarian hormones estrogen and progesterone decrease greatly and menstruation begins[2,3].

With the growing number of women who practice regular physical exercises, the *Brazilian Society of Sports Medicine* in 2000 recommended that the prescription of exercises for women should aim to reduce the deleterious effects of physical inactivity, also taking into account the cardiorespiratory conditioning, muscular endurance and strength, body composition and flexibility of these women before exercise prescription[4].

In addition to reproductive functions, it is speculated that changes in hormone production during different phases of the menstrual cycle may influence other physiological systems, such as: cardiovascular system and skeletal muscle, which may have an impact on physical performance and quality of life. of the women. In this way, it is important to return to the primary understanding about the hormones involved in the MC to study their influences on physical exercises, and increasingly gains value and helps to fill scientific gaps, since little is said about the organization of strategies and intervention. for carrying out physical exercises, sports practices, leisure activities, which take into account the possible impacts and alterations caused by MC and its hormones. Therefore, it is necessary to correlate the influence of the hormones that make up the ovarian and endometrial cycles with the practice of physical exercises, in order to improve the exercise prescription, taking into account the volume, intensity and type of exercise, which can be developed according to the peculiarities of each woman. In this sense, the present study aims to review the influence of MC during the practice of aerobic and resistance exercises.

Material and method

As a search strategy for the present study, narrative review was understood as a category of articles suitable for describing and discussing the development of a given subject. It does not inform the sources of information used, such as the methodology for searching references and the criteria for selecting works, therefore it does not have a methodology that allows the reproduction of data and does not provide quantitative answers to specific questions. They basically consist of an analysis of the literature published in books, articles in printed and/or electronic magazines in the interpretation and personal critical analysis of the author[5].

The search for articles was carried out in the databases: PubMed, Scielo and Google Scholar, from August to September 2021, without restriction on date and type of publication, and all articles in English and Portuguese were considered. The research was based on the phases of the menstrual cycle in eumenorrheic young women, who may or may not be athletes, but without known dysfunctions of the menstrual cycle.

The terms used for the search were: (menstrual cycle OR menstrual phase) AND (physical exercise OR physical activity OR physical performance). Then, duplicates were eliminated and the title and abstract were read, discarding all articles not specific to the topic. From then on, the article was read in full to obtain relevant and clear information that could contribute and elucidate the proposed objective. In addition, the lists of bibliographical references of the selected articles were consulted, in order to insert studies that, perhaps, could be relevant to the discussion proposed in the present study. An overview of the search and screening process is provided in Figure 1.

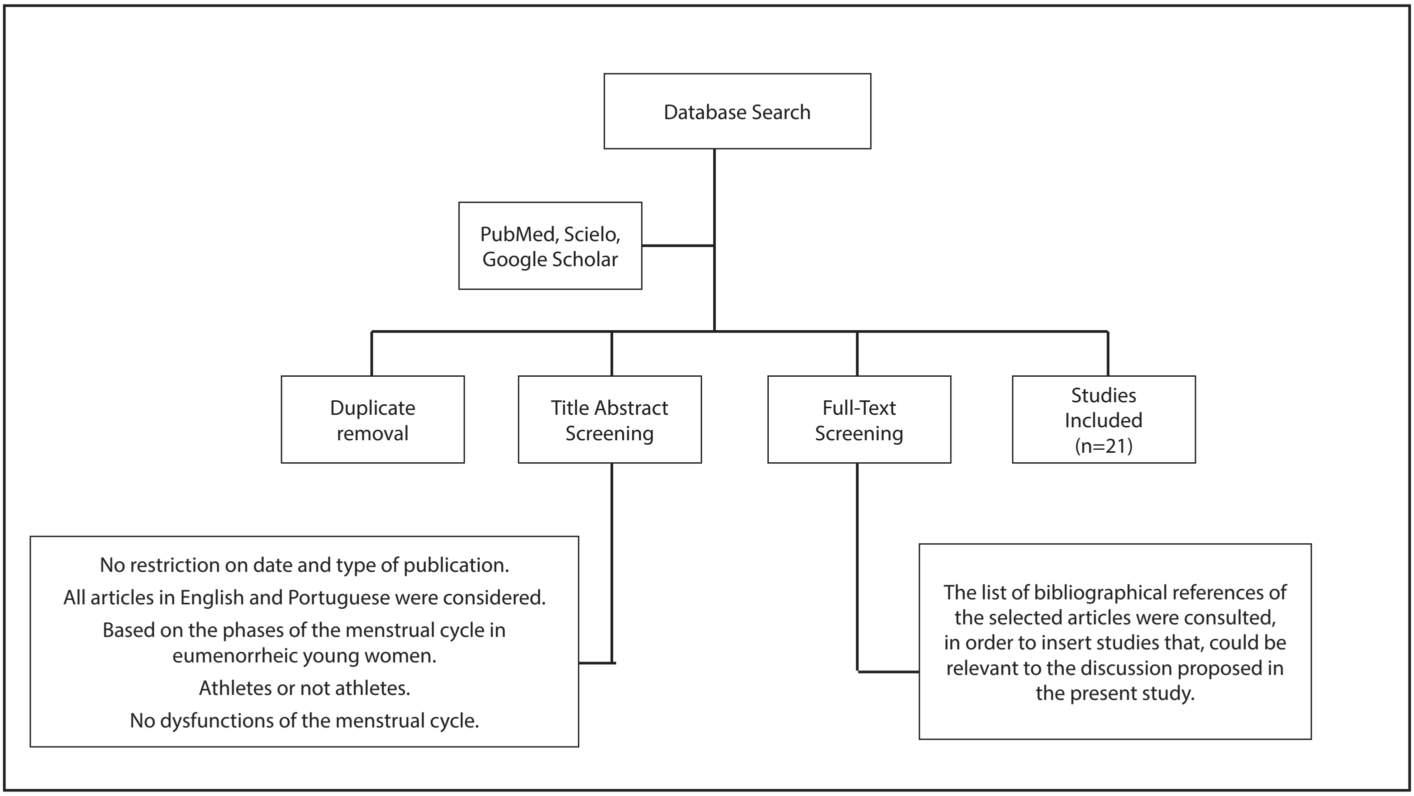
Development

The positive and negative feedback relationship in the hypothalamic-pituitary-ovarian axis can help in understanding variations in physical performance throughout the menstrual cycle. The gonadotropic hormones (LH and FSH) and the ovarian hormones (progesterone and estrogen) play a role in the pituitary, ovarian and endometrial hormonal cycle. However, although the hormonal physiological pattern is widely present in all eumenorrheic women, the concentration and duration of cycle events show great individual variability. These hormonal oscillations generate changes in the perception of the woman's body, such as fluid retention, weight gain, physical performance, as well as changes in mood and sleep, and other variables. Given the complexity of the subject, the aim of this narrative review is to present topics related to the physiology of the hormonal system, female sex hormones, MC itself and its relationship with physical exercise (resistance and aerobic). For a better understanding, a Table 1 was created with the descriptions of the articles included.

Hormones

Hormones are molecules produced by the endocrine glands, secreted into body fluids, and then transported by the blood to target cells. There are different types of hormones that interact with their receptor and trigger a cascade of biochemical reactions in the target cell that eventually modify the cell's function or activity being either general or local. Hormones that affect all or almost all cells in the body are defined as general, however some hormones have only a few target cells and specific receptors, these are designated as local. The target cells of each hormone are characterized by the presence of certain coupling molecules (the receptors) for the hormone that are located on the surface or inside the cell. For instance, ovarian hormones exert specific

Figure 1. Literature review process.



Fuente: autor

effects on the female sex organs as well as the secondary characteristics of women, on the other hand, growth hormone induces the growth of all or almost all parts of the body[6,7].

The female hormonal system presents itself in three hierarchies of hormones: [1] hypothalamic releasing hormone, the gonadotropin-releasing hormone (GnRH); [2] the adeno-pituitary hormones secreted in response to the release hormone of the hypothalamus, follicle-stimulating hormone (FSH) and luteinizing hormone (LH); [3] the ovarian hormones, secreted in response to the two hormones of adeno-pituitary, estrogen and progesterone. These hormones are not secreted constantly occurring changes in levels during the menstrual cycle[6].

Gonadotropins, progesterone and estrogen

Gonadotropins (FSH and LH) are hormones that act on the gonads and these hormones have a clear influence with the menstrual cycle. FSH and LH are small glycoproteins that have observed effects on the ovaries in women, which stimulate their ovarian target cells by combining with highly specific FSH and LH receptors on cell membranes and these activated receptors increase the rate of secretion of these cells, as well as their growth and proliferation. By exposing each one separately, FSH has the function of provoking the growth of follicles and the production of estrogen in the ovaries. Low levels of FSH in women will stimulate estrogen production, whereas high levels will inhibit it. Another gonadotropin is LH, which function is to promote the secretion of estrogen and progesterone, in addition to the follicle rupture, causing the release of the egg[6,8].

The regulation of gonadotropin secretion is quite complex, encompassing pulsatile, periodic, diurnal and cyclic elements involved in the menstrual cycle. The effects of changes in the levels of each of these hormones are influenced by the different stages of a woman's life. Its secretion is controlled by the gonadotropin-releasing hormone (GnRH), secreted by the hypothalamus and acts on the adeno-pituitary[8].

There are estrogens and progestins as far as ovarian hormones are concerned. The most important of the estrogens is estradiol while the most important progestin is progesterone. Steroid or non-steroidal in nature, they are the main mediators of ovarian effects on the hypothalamic-pituitary system. However, ovarian changes during the menstrual cycle are totally dependent on gonadotropic hormones secreted by the anterior pituitary. Estrogens mainly promote the proliferation and growth of specific cells in the body and are responsible for the appearance of most secondary sexual characteristics in women, in addition to stimulating the deposition of body fat, as a way of preparing the mother's body for pregnancy. Its regulation is related to FSH and LH and also depends on the time of life, as well as testosterone[6-8].

Table 1. Description of included studies.

Author(s), year	Purpose of the study	cycle phase	(n)	Protocol or evaluation used	Conclusion
Gil *et al.,* 2017	To analyze the effect of strength training (ST) with blood flow restriction (BFR) training on muscle power and submaximal strength (SS) of upper and lower limbs in eumenorrheic women.	1) EFP 2) OVU 3) LLT	40 women (18–40 years), untrained. (G1) HI ET (low intensity) at 80% of 1RM; (G2) LI TF (high intensity) at 20% of 1RM + BRF; (GC) LI at 20% of 1RM - control group.	Protocol for each group: ST: 8 sessions Tests: Medicine ball (MB), Horizontal jump (HJ), Vertical jump (VJ), Bicep curl (BC) and Knee extension (KE).	ST with BFR does not seem to improve LL and LL potency and may be an alternative to improve LL SS in eumenorrheic women.
Rael *et al.,* 2021	To analyze the impact of sex hormone fluctuations along the MC on the cardiorespiratory response to high-intensity interval exercise in athletes.	1) EFP 2) LFP 3) ELP	Resistance-trained eumenorrheic women.	MC calendar; urinary LH; Serum hormone analysis; Training: 8 × 3 minutes at 85% of your maximum aerobic speed with a 90-second recovery at 30% of your maximum aerobic speed.	It appears that sex hormone fluctuations across the MC are not high enough to disrupt tissue adjustments caused by high-intensity exercise.
Barbosa *et al.*, 2007	Identify the variation in sensory perception and motor response in the different phases of the MC.	1) EFP 2) LFP 3) OVU 4) ELP 5) TLP	30 women (18-40 years old).	Pulse generator: pulsed electrical currents; Sensory Perception Threshold (SPT); Motor response threshold (MST).	SPT and MST varied systematically across the MC phases, influencing sensorimotor behavior.
Darlington *et al.,* 2001	Optokinetic function and postural stability at different MC phases.	1) EFP 2) IFP 3) ELP	16 university physical education students (20-35 years old).	Serum hormone concentrations: estrogen and progesterone.	Although the MC phase has no ↔ in the anteroposterior oscillation , it significantly affected the lateral oscillation, with FFP oscillation significantly > than in the other phases and oscillation on day 25 significantly > than on day 21 of the cycle.
Fouladi *et al.,* 2012	To investigate the effect of CM on knee joint position sense (SDP) in healthy female athletes.	1) EFP 2) MFP 3) ILP	16 healthy athletes.	Measurement: joint position sensor; Serum levels: estrogen and progesterone; Knee Joint Position Measurement (JPS) sensor.	Athletes have different levels of JPS in the knee along the MC. JPS accuracy decreases during menstruation, when circulating levels of sex hormones are low. Therefore, female athletes are > at risk for menstruation injuries.
Fridén *et al.,* 2006	To investigate knee joint kinesthesia and neuro-muscular coordination in women with a moderate level of activity in three well-defined phases of the MC.	1) EFP 2) OVU 3) ILP	32 healthy, moderately active women (25 of them had at least one hormonally verified menstrual cycle).	Kinesthesia of the knee joint; Neuromuscular coordination: jump test.	The variation of sex hormones in the MC has an effect on the performance of knee joint kinesthesia and neuromuscular coordination.
Melegario *et al.,* 2006	To investigate whether there are differences in the degree of flexibility in the MC phases of young adult women practicing academic gymnastics.	1) EFP 2) OVU 3) TLP	20 women (18-35 years old); No use of oral contraceptives.	Consultation: menstrual cycle and physical activity. Flexibility: goniometry with 8 movements. Hormone test: estrone, estradiol and progesterone levels.	The results found showed that there was no ↔ on the degree of flexibility of the studied group, during the different phases of the MC.
César, Pardini and Barros, 2001	Investigate the effects of running training long distances in the MC, bone density, body composition and aerobic power.	1) LUT	Endurance runners and 8 women, non- practitioners of regular physical activity - GC).	Serum levels : estradiol, progesterone and prolactin; Bone density : spine and femur; Lean mass, body fat and % fat; ergospirometric test max; attendance monitoring _ heart training in runners.	The practice of long distance running did not cause menstrual or hormonal disturbances.
Brar , Singh and Kumar, 2015	To observe the effect of MC on cardiac autonomic function parameters in healthy women.	1) EFP 2) LFP 3) ILP	50 young women; cycling practitioners; without using contraceptives.	Heart Rate Variability (HRV)	Increased sympathetic outflow in the secretory phase compared to the proliferative phase and increased parasympathetic outflow in the proliferative phase compared to the secretory phase.

(continued)

Table 1. Description of included studies (continuation).

Author(s), year	Purpose of the study	cycle phase	(n)	Protocol or evaluation used	Conclusion
(Barba-Moreno *et al.,* 2019)	To investigate the effects of these fluctuations on cardiorespiratory responses during steady state exercise in women.	1) EFP 2) IFP 3) LUT to the: 1) HP 2) NHP	23 resistance-trained healthy women, (15 on regular MC and 8 on oral contraceptive cycle).	Test: 40 minutes of running at 75% of your maximum aerobic speed.	The lack of clinical significance of these differences and the non-differences of other physiological variables indicate that MC had a small impact on submaximal exercise in the present study.
Dias *et al.,* 2005	To verify the effect of the different phases of the MC on the performance of the FM in a test of 10 maximum repetitions (10RM).	1) EFP 2) OVU 3) ILP	8 young women (20-25 years old), physically active, practitioners of resistance exercises, who used AO.	Measurements: body weight and height; Strength: 10RM test.	There are no variations in the maximum FM during the different phases of the MC.
Simão *et al.,* 2007	Check if there are differences in the FM levels of the LL and SS.	1) EFP 2) OVU 3) LLT	19 trained eumenorrheic women (21-32 years). Regular MC; experience Minimum 3 years in strength training.	FM: 8RM test, an open front pull on the pulley tall and leg press 45^0.	Influence of MC on the ability to produce FM in LL. For upper limbs, there were practically no load changes in any of the assessed phases.
Ramos *et al.,* 2018	Check the FM of the lower limbs in the four phases of the MC.	1) EFP 2) LFP 3) OVU 4) ELP	15 women (18-39 years old); Bodybuilders; Use of oral or injectable contraceptives.	Submaximal load test on leg device press 45^0.	The MC can influence the strength of the LL.
Romero-Moraleda *et al.*, 2019	Investigate fluctuations in muscle performance.	1) EFP 2) LFP 3) ILP	13 eumenorrheic and resistance-trained women. No contraceptive use.	Pre -experimental test: half-squat 1RM; Body mass; Tympanic temperature; daily urinary LH; On the second day of each phase: Strength: half-squats, with 20, 40, 60 and 80% of 1RM. Load, force, velocity and power: measured during the concentric phase using a rotary encoder.	Eumenorrheic women have similar FM and power performance in the Smith machine half-squat exercise during the three phases of the MC.
Dasa *et al.,* 2021	To investigate the effect of female MC on strength and power performance in highly trained athletes.	1) FOL 2) LUT	29 athletes (8 eumenorrheic women and 21 under hormonal contraceptive use - control group). And team sports: football, handball and volleyball.	F M: maximum voluntary isometric grip; Sprint: 20 m; Jump: counter-movement; Leg-press: pneumatic. levels: confirm cycle phase.	Not observed ↔ performance based on the use of hormonal contraceptives. This suggests that MC does not alter acute FM and power performance at the group level in high-level team athletes.
Lima *et al.,* 2012	Investigate whether there are differences in FM levels between menstrual and post-menstrual periods.	1) EFP 2) LFP	25 sedentary women (18-25 years old), 10 not using contraceptives and 15 using contraceptives.	FM: 1RM test - handgrip dynamometer; Questionnaires: depression , tension syndrome Resumen premenstrual period and changes in mood, physical and depressive.	The study reports a > mean of the forces averages and maximums during the post-menstrual phase, however, there were no differences in handgrip strength between user and non-user women. contraceptive users.
Souza *et al.,* 2015	Check possible alterations caused by the phases of the MC in the production of FM and EMG.	1) FOL 2) OVU 3) LUT	9 healthy, physically active women, not using contraceptives.	FM: MVCs; EMG: rectus femoris (RF), vastus medialis (VM) and vastus lateralis (VL) muscles.	The muscles evaluated in the luteal phase presented > FM production when compared to the other phases and the VL was the most activated muscle in all analyzed phases.

n: sample size; MC: Menstrual Cycle; OA: Oral Contraceptive; EFP: Early Follicular Phase; LFP: Late Follicular Phase; UVO: Ovulatory Phase; ELP: Early Luteal Phase; ILP: Intermediate Luteal Phase; LLP: Late Luteal Phase; FOL: Follicular Phase; LUT: Luteal Phase; HP: Hormonal Phase; NHP: Non-Hormonal Phase; FM: Muscular Strength; 1 RM: One Rep Maximum; MVC: Maximum Voluntary Contraction; EMG: Electromyographic Activity; LL: Lower Limbs; SS: Upper Limbs; >: biggest; <: smallest; ↔ : no difference between MC phases.

On the other hand, progesterone increases the vascularization of the body and mainly the cervix, responsible for preparing the uterus for implantation of the egg, increasing core temperature and preparing the breasts for lactation. In body composition, progesterone increases muscle mass and fat storage[7,8]. During the first half of the ovarian cycle, progesterone appears in small amounts in the plasma, being secreted in approximately equal amounts by the ovaries and the adrenal cortex, whereas in the second half of each ovarian cycle it is significantly secreted by the corpus luteum[6,7].

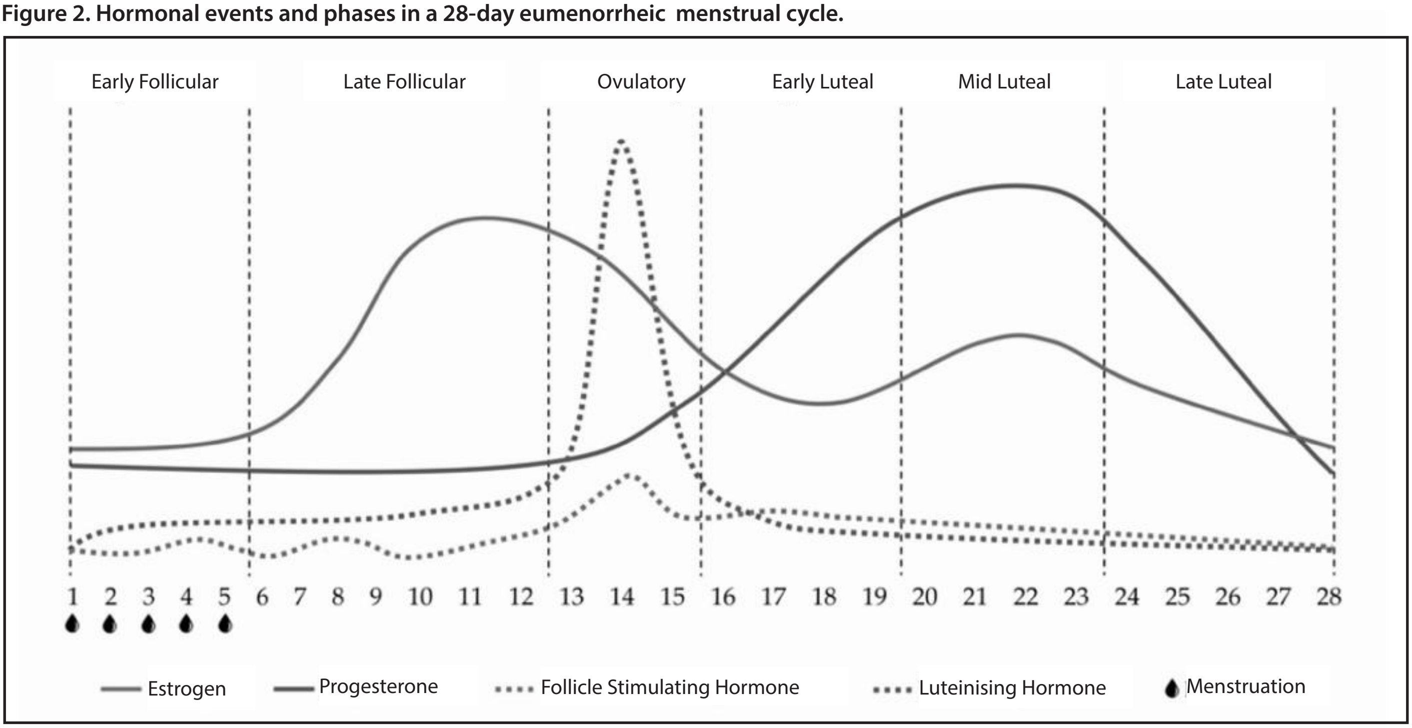
Menstrual cycle

The MC is dependent on endocrine, autocrine, and paracrine factors that regulate ovarian follicular development, ovulation, luteinization, luteolysis, and endometrial remodeling[10]. Ovarian hormones, steroidal or non-steroidal in nature, are the main mediators of ovarian effects on the hypothalamic-pituitary system[11]. The MC has a sequence of circa-monthly rhythms that lasts an average of 28 days, with inter-individual variations, in which there are responses to the concentration of hormones in the hypothalamic-pituitary-ovarian axis.

Endocrine communication between hormones and glands determine the two main phases of MC, separated by mid-cycle ovulation: the follicular phase, which focuses on the maturation of a reproductive cell, and the luteal phase, which is characterized by the formation of the corpus luteum and its regression[1,6,8,12]. However, classifying MC using only these two phases does not sufficiently distinguish the multiple hormonal environments that occur within these two phases. Therefore, MC is typically expressed in surveys using subphases such as: early follicular, late follicular, ovulatory, early luteal, mid-luteal, and late luteal[13].

Despite individual variations, fluctuations in the four major female sex hormones are essential for regulating the patterns of the ovulatory cycle. A few days before menstruation, about two to three days, the corpus luteum involutes, decreasing levels of progesterone, estrogen and inhibin (a glycoprotein hormone, which has a negative feedback effect on the anterior pituitary and hypothalamus). In the absence of fertilization, the endometrium loses its supply and degenerates, breaking down with menstrual bleeding. The early follicular phase (EFP) is considered by the onset of menstruation and usually takes 4 to 6 days to complete. This phase is also characterized by low serum concentration of female hormones. The late follicular phase (LFP) continues until ovulation occurs, during this time estrogen increases as the ovarian follicles mature. Reaching the estrogen peak, there is an increase in the secretion of gonatropin-releasing hormone, which generates a rapid increase in LH. This LH still surges in the LFP triggering ovulation, which follows the rupture of the mature follicle and release of the egg into the uterus. After ovulation, the initial luteal phase occurs, in which the ruptured follicle becomes the corpus luteum and secretes progesterone and a small amount of estrogen. The progesterone peak, with the second peak of less estrogen takes place to prepare the endometrium for implantation of the fertilized egg. This phase ends if a fertilized egg is implanted. But if the egg remains unfertilized, the corpus luteum will be degraded, causing a decline in progesterone and estrogen. In the late luteal phase, the cycle prepares to restart with the shedding of the uterine lining for menstruation to begin again. In MC, the estimated time of each phase is shown in Figure 2, however these phases are variable, mainly due to the moment of ovulation[1,6].

Figure 2. Hormonal events and phases in a 28-day eumenorrheic menstrual cycle.



Adapted from Carmichael *et al.,* 2021.

The relationship between menstrual cycle and physical exercise

Physical exercises are activities systematically programmed with the objective of improving physical performance, promoting improvements in respiratory and cardiac capacity, muscle strength, among others[14]. Physical exercise is considered to be a factor that disturbs the body's homeostasis, which can stimulate the secretion of certain hormones and inhibit others.

Gil *et al.*, 2017 and Rael *et al.*, 2021, explain that physical performance can change throughout a MC due to several mechanisms such as: altered muscle activation, substrate metabolism, thermoregulation and body composition. Female sex hormone concentrations can result in altered strength production, affecting muscle strength and potency. Regarding hormonal effects, estrogen has a neuroexcitatory effect and progesterone inhibits cortical excitability, which result in a positive and negative relationship in strength production. Such studies assume that greater strength and potency results would be produced when progesterone is low during the follicular phase, especially when estrogen reaches peak during the late follicular phase, and lower strength results would be produced in the luteal phase when progesterone is high[10,15].

There is a cyclical regulation of sex hormone levels during MC, which in addition to reproductive functions, can influence other physiological aspects as those related to the cardiovascular system, skeletal muscle and adipose tissue. Some studies suggest that estrogen and progesterone have an influence on aerobic and anaerobic capacity, changes in soft tissues, muscle strength, proprioception, neuromuscular coordination and postural control. Estrogen acts on the CNS and at the cellular level, decreasing collagen production in tendons by attenuating fibroblast activity. In addition to its receptors being present in skeletal muscle, which influences motor control and myofascial force transmission patterns. On the other hand, progesterone during the luteal phase, has a central thermogenic effect increasing body temperature, improving minute ventilation and response to maximal exercise. Still in the luteal phase, the increase in progesterone metabolizes neurosteroids such as: allopregnanolone and pregnanolone which can infer balance and motor function disorders in this phase due to the action on GABA-A receptors[16-19].

Based on this principle, it is assumed that female hormones would be responsible for increased ligament laxity and decreased neuromuscular performance. However, Melegario *et al.*, 2006, in their study with a sample of 20 women who practice gymnastics at a gym, aged between 18 to 35 years, with regular MC and who did not use oral contraceptives, concluded that MC does not interfere with the flexibility variable[20].

Also about connective tissue, Chidi-Ogbolu & Baar, 2019, in a review study, evaluated the effects of estrogen on musculoskeletal function and how these changes affect performance, adaptation and risk of injuries in an active population. The analyzed studies showed that estrogen improves muscle proteostasis and increases collagen content in tendons, however, as more women participate in sports, the physiological effects of estrogen contribute to decrease potency and performance and make women more prone to ligament injuries[21].

Several studies, such as by Carmichael *et al.*, 2021, try to establish whether the MC phase influences muscle and tendon stiffness and whether it can be a risk factor for soft tissue injuries. Some of these studies are presented in the narrative review by (Carmichael *et al.,* 2021) in which the authors present articles that point out that stiffness is affected by the MC phase and can alter performance through changes in tissue stiffness. It has been suggested that increasing estrogen concentration in certain phases of MC can reduce stiffness, decreasing collagen synthesis and therefore collagen density in muscles and connective tissues[13].

Menstrual cycle and aerobic exercises

Cesar, Pardini and Barros, 2001, conducted a study that evaluated women who practiced running and did not practice physical activity to investigate the effects of long-distance running training on the MC and other variables. The practice of long-distance running did not cause menstrual or hormonal disorders, despite the great distances covered weekly by the athletes. Aerobic physical exercise provided the following benefits to runners: greater aerobic power, demonstrated by maximum oxygen consumption and anaerobic threshold, greater lean mass and lower body fat content compared to women who did not practice physical activities[22]. The serum dosage in this study was performed only in the luteal phase (from the 15th day of the MC) which restricts the possible influences of hormonal oscillations on aerobic exercises in other phases of the MC.

Regarding prolonged exercise, De Jonge, 2003, in his review study analyzed the potential effects of fluctuations in female steroid hormones (estrogen and progesterone concentrations) during MC on exercise performance, and exposes that MC may have effect on exercises. Although most research suggest that oxygen consumption, heart rate, and rating of perceived exertion responses to submaximal steady-state exercise are not affected by MC, several studies report an increase in cardiovascular exertion during moderate exercise in the mid-luteal phase. During prolonged exercise in hot conditions, a decrease in exercise time to exhaustion is shown during the mid-luteal phase, when body temperature is elevated. Thus, the mid-luteal phase has a negative potencial effect on prolonged exercise performance through elevated body temperature and potentially increased cardiovascular effort but when it comes to athletes who menstruate regularly and compete in intense aerobic sports, there is no need to adjust the phase of the menstrual cycle to maximize their performance[23]. Unlike the study above which only analyzed the luteal phase of the MC, the De Jonge review in 2003, analyzed studies that measured estrogen and progesterone to check the phase of the menstrual cycle, beisdes that his review speaks very well about the various types of tests used to verify the phases of the MC as well as possible bias in the tests, which helps to guide further research.

The MC hormonal fluctuations are linked to variations in autonomic nervous system (ANS) functions. Physiological changes along the MC can be demonstrated by heart rate variability (HRV) which is a measure of cardiac autonomic tone. Brar, Singh and Kumar, 2015, conducted a study with 50 young women who go cycling regularly, which consisted of analyzing the time and heart rate domain in the different phases of the MC, with the objective of knowing the effect of the MC on the parameters of cardiac autonomic function in healthy women. They concluded that differences in HRV parameters may be due to parasympathetic predominance during the proliferative phase and sympathetic activity in the secretory phase. A difference in the balance of ovarian hormones may be responsible for these changes in autonomic functions during MC[2]. The study excluded women using oral contraceptive pills, serum levels were collected on three different occasions of the MC and always at the same time of day to avoid variations and a complete menstrual history was made, with the nature, flow, regularity and total duration of the cycle but the time in which this history was followed up is not reported.

Responses to submaximal exercise may depend on the MC phase, that is, a less effective cardiorespiratory response may occur with submaximal exercise during the luteal phase when progesterone levels are significantly elevated. However, the lack of clinical results from these differences and the non-differences from other physiological variables indicate that the menstrual cycle has a small impact on submaximal exercise[24]. The study by Barba-Moreno *et al.,* 2019, came to these results after a study of 23 healthy, resistance-trained, eumenorrheic or oral contraceptive users women. Both groups had the same experimental protocol, differing only from the laboratory tests in which the eumenorrheic group had three collections (early follicular phase, medium follicular phase and luteal phase) and the contraceptive group had two collections (non-hormonal phase and hormonal phase). In this study, the history of the MC was also carried out but unlike the previous one, the authors requested information on the last four MC before the beginning of the collections. In the end, the authors Barba-Moreno *et al*., 2019, expose possible limitations regarding the real effects that could be greater or smaller than those reported[24].

The study by Rael *et al*., in 2021, analyzed the impact of sex hormone fluctuations along the MC on the cardiorespiratory response to high-intensity interval exercise in athletes. Ventilation was impacted by the MC phase during warm-up, interval running protocol, and cool-down. On the other hand, HR had the main effect of the MC phase along the high-intensity intervals and it presented lower values in the PEF compared to the PF. However, the authors show that some previous studies have not reported an effect of the MC phase on the HR response to exercise and would suggest that the increase in cardiorespiratory effort due to high-intensity exercise is greater than any possible increase caused by progesterone. Thus, the effect of progesterone on this physiological variable may be hidden by high-intensity exercise[10]. The study by Rael *et al.,* 2021, carried out a three-step method composed of collecting information on the last six MC of the athletes to determine the phases, measurement of urinary LH and serum hormone levels analysis which soon brings a greater reliability for the data, in addition to the study is part of IronFEMME, an observational cross-sectional study carried out with physically active and healthy women.

In conclusion, most studies presented in a recent narrative review concluded that MC phases had no effect on aerobic exercise performance[13]. In short, current results indicate that exercise performance may be reduced during MC phases, especially in the early follicular phase compared to all others. However, due to the effect, the low methodological quality and the great variation among the studies carried out to the present moment, general guidelines on exercise performance in the MC cannot be made, however it is recommended that a personalized approach can be done based on each individual's response to exercise performance in the MC[25].

Menstrual cycle and resistance exercises

When assessing muscle strength, Dias *et al.,* 2005, verified the effect of the different phases of the MC on the strength performance in a 10 RM test of upper and lower limbs. Eight trained women in regular use of oral contraceptives were evaluated. The results showed that in the front pulley pulldown, there were no significant differences in strength when comparing the three phases of the MC. Regarding the leg press, variations were observed without significant differences in the interphase loads, mainly between the follicular and luteal phases. In conclusion, the study reports that there are no significant variations in maximal muscle strength during the different phases of the MC. The authors explain that there is no relationship between the periodization of strength training as a function of the endocrine profile of each phase. Since such fluctuations in serum concentrations of estrogen and progesterone are not enough to affect physical performance, however they explain that there is indeed a decrease in performance along the MC and that these may be the result of some variables considered individual[26]. In another similar study, the authors also collected strength measurements during MC but their sample did not use oral contraceptives. Unlike the previous study, Simão e*t al.,* 2007, reported that there is an influence of the MC on the ability to produce strength in the lower limbs, however it is not seen in the upper limbs that there were practically no changes in load in any of the phases evaluated[27]. In both studies, there were limitations which should be taken care of when extrapolating the results, the sample size, the difficulty in defining the phases of the cycle and the collection in a single MC.

Ramos *et al.,* 2018, wanted to assess lower limb muscle strength in the four phases of the MC and again observed that the MC did not affect muscle strength performance[28]. When investigating the variations in muscle strength, speed and power production in three different phases of the MC in resistance exercises performed with loads equivalent to 20, 40, 60 and 80% of 1RM, in the half-squat of the Smith machine, Romero-Moraleda *et al.,* in 2019, also observed that the MC did not affect muscle performance for the mean and maximum values of strength, speed and power, which suggests that the muscle strength and power performance of eumenorrheic women are not affected by different phases of the MC[1]. The study by Ramos *et al.,* 2018, evaluated muscle strength in the four phases of the MC but it occurred in a single cycle and did not use the collection of serum hormones, whereas Romero-Moraleda *et al.,* 2019, also had a small sample but with triathletes, used a menstrual history of four months prior to regular cycles and evaluated within three phases of the menstrual cycle but there was also no serum dosage of female sex hormones to confirm the duration of the cycle and the beginning and the end of each phase.

Thompson *et al.,* 2020, conducted a systematic review to identify and critically evaluate studies on the effect of MC and oral contraceptives on responses to resistance training. Less than 20 studies met the inclusion criteria but with a limited number of participants and methodological issues. The results suggest conflicting findings that female hormones may affect resistance training responses[29]. Reinforcing these results, the rapid literature review by Cunha *et al.,* 2021, shows that the regular MC of physically active women can exert an effect on physical performance, however such effect was found in the minority of studies[30].

In these reviews, the limited number of articles implies conflicting results, mainly due to methodological issues such as the reduced number of participants, use of contraceptive methods, different ways of evaluating the phases of the MC, exercises and sports.

Studies carried out with athletes especially during competitions can generate sample loss due to different factors such as: injuries, training/competition schedules, besides length individual variation and beginning of the MC and difficulty in taking exams and tests on specific dates of the cycle. In this sense, the study by Dasa *et al.,* 2021, also analyzed the effect of MC on athletic performance. However, they did not find statistically significant changes in the follicular and luteal phases. These findings propose that the MC phase should not be considered important for athletic testing or competition emphasizing strength and power performance[31].

Hormonal fluctuations can alter physical performance but individual variables influenced by hormones can indirectly generate changes in women's performance. In another aspect, thinking about self-assessment and self-report of symptoms, the study by Costa e Silva *et al.,* 2017, evaluated how premenstrual tension syndrome (PMTS) would influence university women's physical activity and quality of life in the Physical Education course. Regarding to daily life physical activity of university students, PMTS generates losses, since sports practice is part of their daily lives and in their academic performance because of the symptoms[32].

The study by Lima *et al.,* 2012, presents results of higher average of the middle and maximum force during the postmenstrual phase. The authors recommend periodizing training to gain muscle strength in relation to hormonal fluctuations within the MC because such fluctuations in serum concentrations of estrogen and progesterone are sufficient to affect physical performance[33]. In agreement with the periodization of training Souza *et al.,* 2015, show that the greater production of isometric strength of the rectus femoris, vastus medialis and vastus lateralis muscles during the luteal phase can be considered a finding for coaches to modify the periodization of training in women under the same conditions. And possibly increase the intensity of training in the luteal phase would be a good alternative for people who wanted more efficient results in strength gain for the lower limbs. In their study, Souza *et al.,* 2015, verified the possible changes caused by the phases of the MC in the production of force and in the electromyographic activity of the quadriceps femoris muscles and the results suggest that the different phases of the MC in women can influence the performance of muscle strength and electromyographic activity[34]. As foreseen in the other studies, some limitations must be considered to extrapolate the results such as: the reduced number of participants, definition of the menstrual cycle of each woman, the use of serum hormone levels and the collection, being restricted by just one MC.

Finally, in their review Carmichael *et al.,* 2021, present that muscle strength was reported in five studies to be affected by the MC phase while another five studies reported no effects and only 1 study reported a change in some strength outcomes and no change in other strength outcomes. Despite inconsistencies in the findings, muscle strength would be impaired during the late luteal phase[13].

Results

As a result of the research, a Table 1 was used that contains elements for a better understanding, it contains experimental studies, with authors and year, phase of the MC studied, sample and sample number, evaluation processes and study development protocols, and to finalize the completion of studies.

It is worth highlighting two reviews related to the proposed theme, the first a systematic review by Thompson, *et al.,* 2020, which aimed to identify and critically evaluate current studies on the effect of the MC and oral contraceptives on responses to training of resistance. Of the 2,007 articles found, only 17 studies met the criteria and were included, with a total of 418 participants aged between 18 and 38 years. The reviewed articles reported conflicting results and were often limited by methodological issues, but it is realized that female hormones can affect resistance training responses[29]. McNulty *et al.,* 2020, also performed a systematic review with meta-analysis, which examined how exercise performance would be affected by the MC phase in 78 studies, and found that there was a trivial reduction in exercise performance during the CM phase. early follicular compared to other phases of the CM. In addition, they brought a network diagram illustrating the pairwise effect sizes calculated in the six phases of CM from 73 studies[25].

Finishing with Carmichael, *et al.*, 2021, who contemplated a narrative review with the aim of complementing some existing systematic reviews, in which they explored the impact of the MC phase on perceived and objectively measured performance in athletic populations. Research has found that the MC plays a mediating role in physical performance and shows that the phases of the MC affect strength, aerobic and anaerobic performance differently. If the training is modified based on the MC phase, the performance variable to be used and the objectives of the sessions must be considered[13].

Conclusions

The present study aimed to review the influence of the MC on the practice of exercises and despite the divergences in the literature, it is considered necessary to relate the variables of the practice of physical exercises with the phases of the MC. Therefore, in the initial follicular phase, lighter exercises are suggested. More intense exercise may be prescribed in the late follicular phase, when estrogen rises and peaks, which affects body fat distribution. In the ovulatory phase, there is the possibility of a decrease in physical performance, but estrogen still circulating maintains physical performance. In the medium luteal phase, there is an increase in progesterone, in which women are more prone to fat loss, so their muscular and aerobic resistance can be developed. With a late luteal phase, hormones begin to drop, but it is worth mentioning that in this phase there is a perception of decreased performance by women, mainly because it is the phase that precedes menstruation, with a new cycle.

Hormonal fluctuations during MC may not significantly and directly affect the cardiorespiratory or musculoskeletal system during physical exercise, as there is the question of the biological individuality of each woman, as well as the relationship with the self-reported symptoms.

By developing this theme, we believe that we can clarify some doubts, but also demonstrate the importance of physiologically understanding the hormones related to BC, for a better performance of several professionals who deal with women inside and outside the competitive environment.

There are several limitations regarding the study and research on MC, namely: difficulty in determining the stages of MC, sample number, type of sample (eumenorrheic women, use of contraceptives or not, what are the dosages of these contraceptives), types of exercises and evaluators of physical performance. So, it remains for future research to determine in which phases of the MC there are oscillations that really influence the practice of physical activity, as well as which exercise prescription strategies, such as intensity and volume, would be ideal for a woman's best performance.

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Conflict of interest

The authors declares that there no conflict of interest.

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