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THE INFLUENCE OF THE MENSTRUAL CYCLE ON STRENGTH TRAINING: A LITERATURE REVIEW

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Abstract. Introduction: To evaluate the existing scientific literature on the relationship between hormonal fluctuations and the ability to produce strength, and to establish which phase of the MC is the most appropriate to apply greater load in strength training. Method: A bibliographic search was carried out using the PubMed database. The articles included were those written in English or Spanish and related to strength production in eumenorrheic women. Results: In terms of grip strength, very different results were obtained, which may derive from the level of training of the participants, as well as from the method used to determine the phases since few of them coincided. If we observe those related to isometric strength, no significant differences were obtained throughout the menstrual cycle, although it would be necessary to look at the phases evaluated and the method used to evaluate these phases. Regarding lower limb strength, the results indicated better strength values in the follicular phase. Finally, the results related to maximum voluntary contraction indicated better values in the luteal and ovulation phases. Discussion and conclusion: In conclusion, the capacity to produce force is greater in different phases according to the strength test performed, the greatest uncertainty was in the grip strength where it is not clear which phase produces the greatest force since the results are very different. However, it seems that the capacity to generate isometric force does not vary throughout the menstrual cycle and the maximum force is related to the follicular phase where the estrogen peak occurs. As for maximal voluntary contraction, two different results are given that offer doubts as to which phase generates more of this type of force.

Keywords: Health, performance, female, sport, sex hormones, menstrual phase.

LA INFLUENCIA DEL CICLO MENSTRUAL EN EL ENTRENAMIENTO DE FUERZA: REVISIÓN BIBLIOGRÁFICA

Resumen. Introducción: Evaluar la literatura científica existente sobre la relación entre las fluctuaciones hormonales y la capacidad de producir fuerza, y establecer qué fase del CM es la más adecuada para aplicar mayor carga en entrenamiento de fuerza. Método: Se realizó una búsqueda bibliográfica a través de la base de datos PubMed. Los artículos incluidos fueron aquellos que estuvieran redactados en inglés o español y que estuvieran relacionados con la producción de fuerza en mujeres eumenorreicas. Resultados: En cuanto a la fuerza de prensión se obtuvieron resultados muy dispares que pueden derivar del nivel de entrenamiento de las participantes, así como del método utilizado para determinar las fases, ya que pocos coincidieron. Si observamos los estudios relacionados con la fuerza isométrica no se obtuvieron diferencias significativas a lo largo del ciclo menstrual, aunque habría que fijarse en las fases evaluadas y el método para evaluar dichas fases. En cuanto a la fuerza del miembro inferior los resultados indicaron mejores valores de fuerza en la fase folicular. Por último, los resultados relacionados con la contracción voluntaria máxima indicaron mejores valores en la fase lútea y de ovulación. Discusión y conclusión: En conclusión, la capacidad de producir fuerza es mayor en diferentes fases según la prueba de fuerza realizada, la mayor incertidumbre se dio en la fuerza de prensión donde no queda clara cuál es la fase en la que se produce mayor fuerza ya que los resultados son muy diferentes. Sin embargo, parece que la capacidad para generar fuerza isométrica no varía a lo largo del ciclo menstrual y la fuerza máxima está relacionada con la fase folicular donde se da el pico de estrógeno. En cuanto a la contracción voluntaria máxima se dan dos resultados diferentes que ofrecen dudas sobre en qué fase se genera más este tipo de fuerza.

Palabras clave: Salud, rendimiento, mujer, deporte, hormonas sexuales, fase menstrual.

Introduction

Over the past three decades, there has been an increase in the number of women participating in exercise, from physical activity to elite sport, attributable to the increasing development and investment in women's professional sport (McNulty et al., 2020). Specifically, the percentage of women competing in the Olympic Games has risen from 26% in Seoul in 1988 to 45% in Rio de Janeiro in 2016. In addition, Tokyo 2021 became the most gender-balanced Games in history, with equal numbers of medals available for men and women, predicting that women's participation in the Games will increase to 49% (McNulty et al., 2020). One of the physiological differences between the two sexes is the menstrual cycle (MC), the main aspect that influences women's sports practice. The influence of CM on the endocrine system and its relationship to physical performance in women has attracted increasing interest from athletes, coaches, physicians, and researchers and represents a developing line of research (Duaso et al., 2018).

The CM is a physiological period from the beginning of bleeding (day 0) until the day before the next bleeding (more or less 28 days), during this period there are physiological undulations of the 4 hormones: estrogen, progesterone, follicle stimulating and luteinizing hormones (Lago Fuentes, 2020). The menstrual cycle is usually divided into two phases, follicular and luteal, or into three, adding the ovulatory phase in between both (Duaso et al., 2018), although there are studies that divide it into up to seven phases. However, the classification of MC using only two phases does not sufficiently distinguish the multiple hormonal milieus that occur within these two phases. Therefore, CM is typically expressed in research using sub-phases, such as early follicular, late follicular, ovulatory, luteal, and premenstrual (Carmichael et al., 2021). The duration of the menstrual cycle throughout life ranges from puberty to menopause, interrupted only by pregnancy, lactation or particular pathologies. Its regularity is sensitive to factors,such as stress, emotional problems, surgical interventions, and disease (Zanin et al., 2011).

The early follicular phase begins with menstruation (bleeding phase) which usually takes 4 to 6 days to complete; in this phase, female sex hormone concentrations are relatively low and stable (Carmichael et al., 2021). The late follicular phase lasts until ovulation and the highest peak estrogen concentration coincides with low progesterone levels. Before ovulation, there is a decrease in estrogen concentration in order to promote ovulation (increase of luteinizing hormone to promote fertilization) (Lago Fuentes, 2020). Finally, the luteal phase begins a few hours after the oocyte has been expelled from the mature follicle. The corpus luteum secretes progesterone reaching its highest peak and a lower amount of estrogen (Zanin et al., 2011). Under the influence of both hormones, but especially progesterone, the endometrium begins its secretory phase, which is indispensable in preparing the uterus for implantation in case the oocyte is fertilized. If there is no implantation the corpus luteum degenerates in a few days as hormone concentrations decrease, this leads to triggering a new menstruation as the endometrium is detached from the uterus (Zanin et al., 2011).

Therefore, during these phases of CM there are two main hormones that vary in concentration throughout CM. The first is estrogen, a hormone with a putative anabolic function, i.e., it promotes muscle growth, whereas progesterone has been linked to catabolic pathways (Romero-Moraleda et al., 2019). Estrogen has an influence on type 1 collagen both in relation to decrease and degradation, increase of elastic content, decrease of fiber diameter and density. On the other hand, progesterone is connected with an increased number of fibroblasts and collagen synthesis. Many of these variables could be connected to the physical performance of female athletes in general, and to their levels of force production in particular (Duaso et al., 2018).

The influence of these hormones and CM phases on the ability to generate force is not entirely clear, with several studies showing contradictory results. Some studies showed greater strength during the follicular phase than during the luteal phase, while other studies reported greater strength during the luteal phase, while most studies could not find any alteration in muscle strength during CM (Sung et al., 2014). It is therefore clear that no agreement has been reached regarding the effects of CM on exercise performance; to date, there are no conclusive results regarding the effects of CM on force-generating capacity. Therefore, the objective of this work was to evaluate the existing scientific literature on the relationship between hormonal fluctuations and the ability to produce strength, and to establish which phase of the CM is the most appropriate to apply greater load in strength training

Method

Search strategy

The search for studies was performed in the PubMed database. The keywords used for the search were "menstrual cycle, strength, sex hormones, performance, menstrual phases and sport".

Inclusion and exclusion criteria

In this work, studies related to the production of strength in women were included; those that focused only on men were excluded; studies with women with a menstrual cycle were included, therefore, those involving preadolescent, menopausal, premenopausal or postmenopausal women were excluded; and studies with women with

a natural menstrual cycle were included, therefore, those involving women using contraceptive treatments were excluded.

Types of studies collected

Experimental studies were collected for this work.

Languages

The search for studies was conducted in English and studies in English and Spanish were accepted.

Search period

A search for studies from 1996 onwards was carried out.

Type of participants

We searched for studies involving women with a menstrual cycle, who were eumenorrheic and who were not using any type of contraceptive treatment.

Results

Figure 1 shows the literature search and the selection of studies included in the review

Figure 1

PRISMA flowchart of this revision

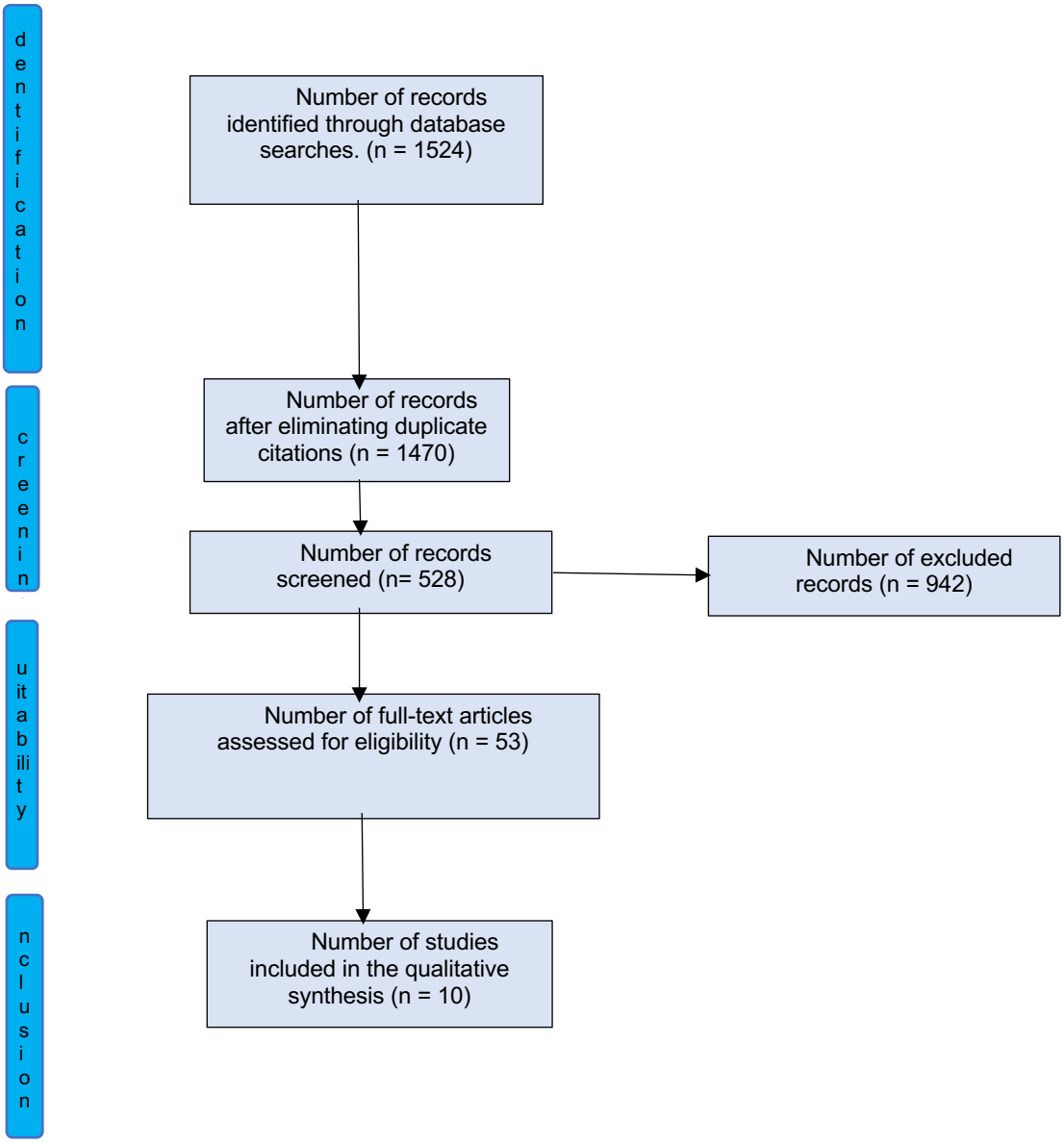

Table 1 shows the results obtained from the different studies analyzed, describing the most relevant aspects:

Table 1

Summary of the results obtained from the analyzed studies

Author and Date	Target	Participants	Method	Phase of the menstrual cycle	Evaluation of the phases	Results
(Dasa et al., 2021)	To investigate the effect of menstrual cycles on strength performance in highly trained female team athletes throughout the menstrual cycle and to examine whether eumenorrheic participants with natural hormonal fluctuations showed improved FF versus FL performance	Eumenorrean women in sports such as soccer, handball and volleyball competing at the national level. (n=8)	Maximal voluntary isometric isometric grip strength of the dominant hand was measured using a digital pinch/grip analyzer and the pneumatic leg press.	FF FL	By serum hormone levels through non-fasting venous blood samples prior to testing at each visit.	There were no statistically significant changes for the two different phases of the menstrual cycle, in terms of physical performance. As for the isometric pressure strength test the highest values were in the LF. In the leg press test, the values were practically similar throughout the menstrual cycle, with the FF being the one that registered the best value.
(Iwanska et al., 2021)	To investigate the effect of the menstrual cycle on strength in physically active women.	Physically active and eumenorrheic women (n=24)	Muscle strength was assessed as ankle flexor muscle pairs in CVM were measured under isometric conditions using the specially designed measuring stand. Two measurements were performed, one at a 90º angle and the other at a 60º angle for all the joints of the lower limb.	Follicular Phase. Luteal phase.	Blood samples were taken from the antecubital vein to determine sex steroid concentrations.	Higher values were documented in both phases for the 90° angle at the ankle joint. Muscle torque in the stretched muscle ($\alpha = 60°$) was 11 % lower on average. MVC was higher in the luteal phase for both angles.
(Janse de Jonge et al., 2001)	To study the influence of the different phases of the menstrual cycle on the contractile characteristics of skeletal muscle.	Eumenorrheic women (n = 15)	An adjustable chair with a steel frame and straight back was used to measure the isometric strength of the quadriceps. The grip strength of the dominant hand was measured using a force transducer placed inside an adjustable frame.	Menstruation phase. Late follicular phase. Luteal phase.	Fasting blood samples were taken from an antecubital vein to measure serum concentrations of estrogen, progesterone, FSH and LH using kits.	There were no significant differences between the phases of the menstrual cycle for any of the variables. No significant changes over menstrual cycle phases were shown for quadriceps isometric strength. For grip strength, no significant changes were also shown throughout the menstrual cycle.
(Kuehne et al., 2021)	To examine changes in muscle strength across menstrual cycles in women.	Eumenorrheic women regularly participated in resistance training	For upper body isometric strength testing, individuals sat on a preacher curl bench with the elbow flexed at 90° and were asked to flex the arm as hard as possible against an immovable object. Isometric force was measured with a load cell.	Menstrual phase. Ovulation phase. Luteal phase.	The Flo app and use of home ovulation kits were used to validate the ovulation phase.	The phase of the menstrual cycle does not seem to influence isometric strength. Isometric strength levels were very similar throughout the 3 menstrual phases.

		(n=14).				
(Miyazaki et al., 2022)	To determine the effect of the menstrual cycle on hamstring strength.	Healthy young women (n=16)	Isometric muscle strength was measured in prone position with 90º knee flexion using an isokinetic dynamometer. Maximal muscle strength was defined as the exercise of force at maximum effort for 3 seconds.	Follicular phase. Ovulation phase. Luteal phase.	The follicular phase (3 days after the end of menstruation), the luteal phase (6 to 8 days before the next scheduled onset of menstruation) and the ovulation phase (2 to 3 days after the ovulation test was positive) were determined according to menstruation	Isometric muscle strength showed no significant difference between the follicular and ovulatory phases. However, there was a significant increase in the luteal phase compared to the ovulatory phase
(Pallavi et al., 2017)	To evaluate variations in muscle strength during various phases of the menstrual cycle in young adults.	Untrained or poorly trained eumenorrheic students. (n=100)	To assess muscle strength, the Mosso Ergograph and Hand Dynamometer was chosen as the testing tool.	Menstrual phase. Follicular phase. Luteal phase.	No evaluation of hormone levels was performed to confirm the phases.	Manual grip strength was significantly higher in the follicular phase and relatively reduced in the menstrual and luteal phases of the menstrual cycle. The menstrual phase has the lowest strength compared to the other two phases.
(Romero-Moraleda et al., 2019)	To investigate fluctuations in muscle performance in the half squat exercise on the Smith machine during three different phases of the menstrual cycle.	Triathletes, eumenorrheic and strength-trained women (n=13)	Half squat on the Smith machine at maximum speed with loads representing 20, 40, 60 and 80% of their 1RM.	FFTemprana FFTardía FLM.	We used: a) period tracking application; b) measurement of tympanic temperature and changes in body mass and c) evaluation of peak urinary luteinizing hormone.	**Maximum strength:** At 20 and 40% of 1 MR, there were no significant differences. At 60% of 1RM, it was possibly greater in the FFTemprana compared to the FLM. At 80% of 1RM, it was possibly greater in the FFTardía compared to the FFTemprana and FLM.
(Sarwar et al., 1996)	To investigate the effect of different phases of the menstrual cycle on skeletal muscle strength and contractile properties.	Young, healthy and relatively sedentary women. (n=10)	Quadriceps MVC was measured using a conventional strength test chair. Grip strength was measured using a Jamar hydraulic hand-held dynamometer, with the arm at the side of the body and the elbow extended.	Early follicular phase. Middle follicular phase. Ovulation phase. Mid luteal phase. Late luteal phase.	They were estimated from the first day of bleeding and the ovulation phase was predicted as 14 days before menstruation. Early follicular phase (between days 1-7), mid follicular (between days 7-12), ovulation (between days 12- 18), mid luteal (between days 18-21) and late luteal (between days 21-32).	There was a significant increase of about 11% in quadriceps and hand grip strength at mid-cycle compared to the follicular and luteal phases. Quadriceps strength peaked during the ovulation phase. There were significant differences in MVC between the ovulatory phase and all other phases of the cycle, with the greatest difference being between the ovulatory and late luteal phases. Grip strength was also significantly higher in the ovulation phase compared to all other phases.
(Shalfawi et al., 2021)	To examine changes in strength in eumenorrheic young female college students during the menstruation phase and at	Eumenorrheic university students, their activity level was limited to physical	Participants tested on bench press one repetition maximum (1RM), leg press 1RM, push-ups to failure, leg press with 60% of 1RM to failure.	Early follicular phase. Late follicular phase. Ovulation phase.	It was based on the classical model of the menstrual cycle, the early follicular phase (day 2), late follicular phase (day 8), ovulation phase (day 14) and mid-luteal phase (day 21).	The results of the present study showed no significant differences in maximal strength or endurance strength tests for both lower and upper body. The highest values were observed in the late follicular phase.

	different testing occasions within a menstrual cycle.	education classes and recreational activities. (n=12)		Mid luteal phase.		
(Weidauer et al., 2020)	To determine changes in neuromuscular performance throughout the menstrual cycle.	Physically active university students (n=22)	Grip strength on the dominant side was measured using the Grip-D digital grip strength dynamometer.	Early follicular phase. Ovulatory phase. Mid luteal phase.	Blood was drawn from a vein in the antecubital region to measure plasma estradiol and progesterone. In addition, they took an ovulation test at home every day starting on day 7, which indicated when the LH surge occurred before ovulation.	Grasping force was greater in the ovulatory and mid-luteal phase than in the early follicular phase.

Note: FF: Follicular phase**,** FL: Luteal phase, CVM: Maximum voluntary contraction, HFE: Follicle stimulating hormone, FSH: Luteinizing hormone, FFTemprana: Early follicular phase, FFTardia: Late follicular phase, LMP: Mid luteal phase

Discussion and conclusions

The results obtained in the different studies on the influence of the menstrual cycle on grip strength are very contradictory. It seems that the phase of the menstrual cycle in which the production of gripping force is greatest is not fully defined. Following a study carried out with sportswomen, they have shown better strength values during the luteal phase (Dasa et al., 2021)which clashes with the results of a study with untrained students where better strength values have been obtained in the follicular phase (Pallavi et al., 2017). This generates a great deal of doubt since the predominant hormone in each is different, but it must be taken into account that the phases evaluated are few and far between, an aspect that may influence the results. In addition, it may be that the physical preparation of the participants may influence the results, since we are talking about athletes and students. On the other hand, two authors (Sarwar et al., 1996) y (Weidauer et al., 2020) who with their studies agree that the best values of clamp force occur in the ovulation phase where the predominant hormone is luteinizing hormone, but if we observe the method of evaluation of this phase is different from each other and it may be that the method used by (Sarwar et al., 1996) is not entirely effective since it predicts the ovulation phase 14 days before menstruation without any type of test that can confirm the phase. On the other hand, (Weidauer et al., 2020) to confirm the ovulation phase has asked the participants to take an ovulation test at home every day from the seventh day until positive, a more efficient method that allows confirmation and testing at that phase. Finally, (Janse De Jonge et al., 2001) in his study found no significant differences throughout the menstrual cycle, although he left some phases to be evaluated, such as ovulation, and observing the previous results, he may have found some difference. Therefore, there are many differences between these studies since the level of training of the participants is very diverse, as well as the methods of evaluation of the phases and the number of phases evaluated, all of which makes the results very confusing and not entirely reliable.

In this case there is a coincidence among the three studies (Janse De Jonge et al., 2001; Kuehne et al., 2021; Miyazaki & Maeda, 2022), all have recorded that there are no significant changes in isometric strength throughout the menstrual cycle, these data agree with those obtained by (Arazi et al., 2019), who have also found no differences in isometric strength throughout the menstrual cycle. The phases evaluated I think are few and far between, (Janse De Jonge et al., 2001) I believe they use an adequate method to evaluate the phases as they measure estrogen, progesterone, FSH and LH through blood samples, thus being able to confirm the phase of the cycle. On the other hand, (Kuehne et al., 2021 and Miyazaki & Maeda, 2022) did evaluate the ovulation phase although the method for determining the phases may not be very effective since the first uses an app and ovulation kits, with the participants having a great responsibility when recording the phases and the second establishes the phases based on menstruation, something that may not be very accurate and reliable.

Two studies have evaluated lower limb strength. (Romero-Moraleda et al., 2019) have performed a half squat study with different percentages of 1RM observing only differences with percentages of 60 and 80% in which the best values were obtained in the early and late follicular phase respectively, coinciding the late follicular phase with the highest estrogen peak, thus supporting the hypothesis put forward by (Smith et al., 1999) suggesting that higher strength values can be observed because estrogen is higher in the late follicular phase. In addition, to determine the phases of the cycle, they have used three types of measurements as recommended by (Bambaeichi et al., 2004 and Tenan et al., 2016) that allow to effectively control and determine the phases. Results that have a slight coincidence with (Shalfawi & el Kailani, 2021) which has performed 1RM leg press and which has evaluated a large number of phases that have allowed them to achieve more accurate results, although they have used a method that is not very valid since it is based on the classical model of the menstrual cycle and does not

perform any type of test to validate and determine the phase of the cycle. The results did not show major differences between the phases, but the best values were recorded in the late follicular phase.

As limitations, few studies related to strength and the menstrual cycle have been found. In addition, in most of them the methods of evaluation of the menstrual phase are different and different strength tests are performed.

Regarding the main objective of this study, we can conclude that the ability to produce force is greater in different phases depending on the strength test performed, the greatest uncertainty is in the grip strength where it is not clear which phase produces the greatest force since the results are very different. However, it appears that the ability to generate isometric force does not vary throughout the menstrual cycle and maximal force is related to the follicular phase where the estrogen peak occurs. As for the maximum voluntary contraction, two different results are given, which raise doubts as to which phase generates more of this type of force. I believe that the level of training of the participants and the method of determining the phases greatly influences the results, an aspect that should be standardized for future studies related to the menstrual cycle.

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