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Hand grips strength in athletic and non-athletic girls at different phases of menstrual cycle: an observational case–control study

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Abstract

Background There are a significant number of female athletes competing at the highest levels of sport. But, women are still largely underrepresented in scientific literature. The female menstrual cycle is characterized by variations in circulating hormone levels, which may have an impact on performance.

Aim This study aimed to assess the impact of hormonal changes through different menstrual cycle phases on hand grip strength, pulp pinch strength, three fingers pinch strength, and lateral pinch strength of athletic and non-athletic girls.

Methods An observational case control study was conducted on forty post-pubertal girls, their ages ranged from 16 to 22 years old, and their body mass index (BMI) ranged from 18.5 to 25 kg/m^2. They were divided into two groups: athletic group of twenty basketball and tennis players recruited from basketball and tennis teams at Mena Garden City Club, 6 October Club, and Shooting Club October and non-athletic group of twenty non-sportive undergraduate students from Faculty of Physical Therapy, Misr University for Science and Technology. Hand grip strength was evaluated by Jamar hand dynamometer, while pulp pinch strength, three fingers pinch strength, and lateral pinch strength were evaluated by Jamar pinch gauge through three different menstrual cycle phases (follicular, ovulatory and luteal phases).

Results Statistical analysis demonstrated a significant increase in handgrip strength, pulp pinch strength, three fingers pinch strength, and lateral pinch strength in non-athletic group. Also, there was a significant increase in three fingers pinch strength and lateral pinch strength in athletic group during the ovulatory phase across the menstrual cycle ($p < 0.05$). But, there was a significant difference across menstrual phases in handgrip strength and pulp pinch strength in athletic group ($p > 0.05$).

Conclusion Hormonal changes during menstrual cycle phases do not alter handgrip strength, pulp pinch strength performance for athletic girls. But, they alter hand grip strength, pulp pinch strength, three fingers, and lateral pinch grip strength performance for non-athletic girls.

Trial registration The protocol of the study was registered in clinical trials.gov PRS (Protocol Registration and Result System (registration No.NCT06086262), Registered on 17 October 2023). The study received ethical approval

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from the Institutional Review Board of the Faculty of Physical Therapy at Cairo University prior to its beginning (approval No P.T.REC/012/003358) .

Keywords Menstrual cycle, Female sex hormones, Athletic female, Performance, Strength

Introduction

Research attention in the physiological and metabolic reactions of females to exercise has expanded as more women play sports. Several studies have been conducted in the last decade to gain deeper insights into the connection between exercise and the menstrual cycle, with a particular emphasis on the hormonal mechanisms regulating menses [1].

Menstrual cycle phases may influence women's performance in sports. Muscle strength, endurance, and metabolism can all vary due to hormonal alterations throughout the cycle [2]. The interactions between physical exercise and hormone responses can be modulated by various physiological factors, like menstrual cycle, physical conditioning, dietary status, and psychological stress level. Throughout the menstrual cycle, certain physiological parameters and an athlete's performance may change. The alterations in such physiological traits across different systems are connected to variations in hormone concentrations [2].

Variations in key female reproductive hormones, estrogen, progesterone, follicle-stimulating hormone, and luteinizing hormone are critical for the regulation of ovulatory cycle patterns. Estrogen is a hormone that is thought to have an anabolic function, whereas progesterone is implicated in catabolism. Considering these variations in hormonal actions, it has been proposed that hormonal variations across the menstrual cycle may impact skeletal muscle performance [3].

Menstrual phase has previously been indicated as a potential factor affecting muscular strength in prior research [4]. The force generation ability generally declines after ovulation by 8 to 23% before increasing again just before menstruation [4]. In general, maximal force production rises during the follicular phase [4]. On the other hand, a different study found no differences in maximal isometric quadriceps strength between menstrual, late follicular, and luteal phases [5]. Earlier studies [4, 5] have concentrated on lower limb muscles or overall body performance.

Hand grip strength reflects total muscle strength and physical fitness [6]. Grip strength is a crucial component for success in various activities, ranging from sports such as tennis, baseball, and basketball, to everyday tasks like carrying laundry, opening doors, and operating a vacuum cleaner. Tennis players, for example, are at risk of developing lateral epicondylitis, if their grip and forearm strength are inadequate. The strength of one's grip, which is often overlooked or taken for granted, has a pivotal role in preventing injuries and developing overall strength [7]. For this reason, the current study aimed to assess the effect of hormonal changes on hand grip strength, pulp pinch strength, three fingers strength, and lateral pinch strength through follicular, ovulation, and luteal phases in athletic and non-athletic groups. It was hypothesized that there would not be differences in grip strength, pulp pinch strength, three fingers strength, and lateral pinch strength through menstrual phases in athletic and non-athletic groups. Also, there would not be differences between athletic group and nonathletic group in all hand grips strength through menstrual cycle.

Methods

Design

An observational case control study was conducted on forty post-pubertal girls. The study received ethical approval from the Institutional Review Board of the Faculty of Physical Therapy at Cairo University prior to its beginning [No P.T.REC/012/003358] and registered as clinical trial [No NCT06086262]. The study followed the Declaration of Helsinki guidelines for conducting human research. The phase of data collection lasted for six months between November 2021 and April. 2022.

Participant

Forty healthy post-pubertal virginal females participated in this study. A written informed consent was obtained from each participant and their caregivers after clarifying the study's purpose and their right to withdraw from the study at any point by signing the appropriate informed consent paperwork.

To be eligible for the study, participants needed to have regular menstrual cycles, confirmed by using a calendar for three consecutive menstrual cycles; their ages was ranged from 16 to 22 years old, and their body mass index (BMI) ranged from 18.5 to 25 kg/m^2. For the athletic group, they had participated in basketball and tennis teams for 3 to 4 years, three times per week, and two hours in each time. For non-athletic group, they had not participated in any regular sports. All participants have the same socioeconomic status. Participants were excluded from the study if they had irregular menstrual cycle with a history of painful menstruation; pelvic inflammatory disease; pelvic infections; any gynecological diseases; and any musculoskeletal disorders of upper extremity or surgery, cardiovascular, pulmonary, neurological, or systemic conditions or females receiving hormonal medications.

Assessment procedures

Detection of the timing of phases of menstrual cycle

Calendar

Each girl maintained a 3-month calendar to document the onset and end of their last three consecutive menstrual cycles. Using this calendar, the mean cycle length was calculated to establish the target dates for all testing sessions. Testing was done during early follicular phase (first 5 days of the menstrual cycle), ovulation days (13th, 14th, and 15thdays), and mid-luteal phase (days from 20 to 25th) of a 28-day normal menstrual cycle [8].

Detection of the exact timing of ovulation

Luteinizing hormone urine strip test is a valid and reliable test to determine exact timing of ovulation [9]. It was given to all females, and they were instructed to start using it on 13th, 14th, or 15th days after the beginning of their cycle, since the average cycle length was 28 days. Participants received instructions about immediately contacting the researcher upon obtaining a positive finding to arrange for data collection [9].

All females were asked to gather a urine specimen in a clean, dry container, and then one strip was taken and immersed in the urine sample up to max line with the arrow end pointing down. After 5 s, the strip was removed and put on a clean, dry, and non-absorbent surface. The result appeared within 5 min. The result was positive if two visible lines appeared or when the test line was darker than the control one (that mean that the ovulation occurred in the next 24–28 h). However, the result was negative when one line appeared in control zone or when the test line was lighter than the control one [9]

Hand grip strength measurement

The evaluation of grip strength in the dominant hand was conducted using a reliable and valid assessment tool, the Jamar adjustable hydraulic handgrip dynamometer (Product model J00105, U.S.A). This device is specifically designed to measure isometric hand grip force in kilograms (Kg) and has been proven to have high levels of reliability and validity (ICC is 0.996 and 0.999) [10]. Females were positioned in an upright seated posture with shoulders in adduction and neutral rotation, elbows in flexion at a right angle, forearms in a natural position, and wrists in a slight extension, resting on armrests. The dynamometer was grasped without any external support, ensuring that it did not make contact with the female's trunk. The position of the hand was consistently maintained without exerting any downward pressure [11]. The researcher calibrated the dynamometer to zero and adjusted to accommodate the hand size. Every female participant underwent a trial warm-up to familiarize themselves with the equipment and the process of recording. Each female performed a trial warm-up to familiarize themselves with the equipment and recording process. The testing procedure involved three maximal isometric contractions of the dominant hand, each lasting 5 s. Between each contraction, there was a resting duration of one minute as a minimum. To determine the maximal hand grip strength, the highest value was utilized [12].

Pinch strength measurement

The evaluation of the three fundamental pinching types, i.e., three fingered pinch (or "chuck," involving pinching the thumb, index and middle fingers together at their tips), lateral pinch (or "key" resembling key-holding), and pulp pinch (with tips) of dominant hand, was conducted for each girl in both the athletic and nonathletic groups. This assessment was carried out using a hydraulic pinch gauge device (Jamar, Model 65,861, USA), which is a reliable and valid evaluation tool with an ICC of 0.98 and 0.99. The device is specifically designed to measure isometric pinch force in (Kg) [10]. Participants were seated upright with shoulders in adduction and neutral rotation and elbows in 90-degree flexion. The pinch gauge was slightly supported by the researcher [11]. First, the researcher calibrated the pinch gauge to zero. Next, the participant was asked to perform a trial warm-up to become familiar with the equipment and recording process. The testing procedure involved three maximal isometric contractions of the dominant hand fingers, each lasting 5 s. Between each contraction, there was a resting duration of one minute as a minimum. To determine the maximal pinch force, the highest value was utilized. The girls received instructions about exerting maximum force on the dynamometer [12].

Sample size estimation

To determine an adequate sample size, the G*POWER statistical software (version 3.1.9.2; Franz Faul, University Kiel, Germany) was utilized. To obtain 80% statistical power (1-β error probability), $\beta = 0.2$ with an α error level probability (type I error) $\alpha = 0.05$, and an effect size of $F = 0.29$. F-tests: MANOVA, Repeated-measure, between subject was used. The minimum required total sample size was estimated to be 34 (Fig. 1). The sample was increased to 40 (20 in each group) to allow for a 10% dropout rate (Fig. 2). This effect size was determined

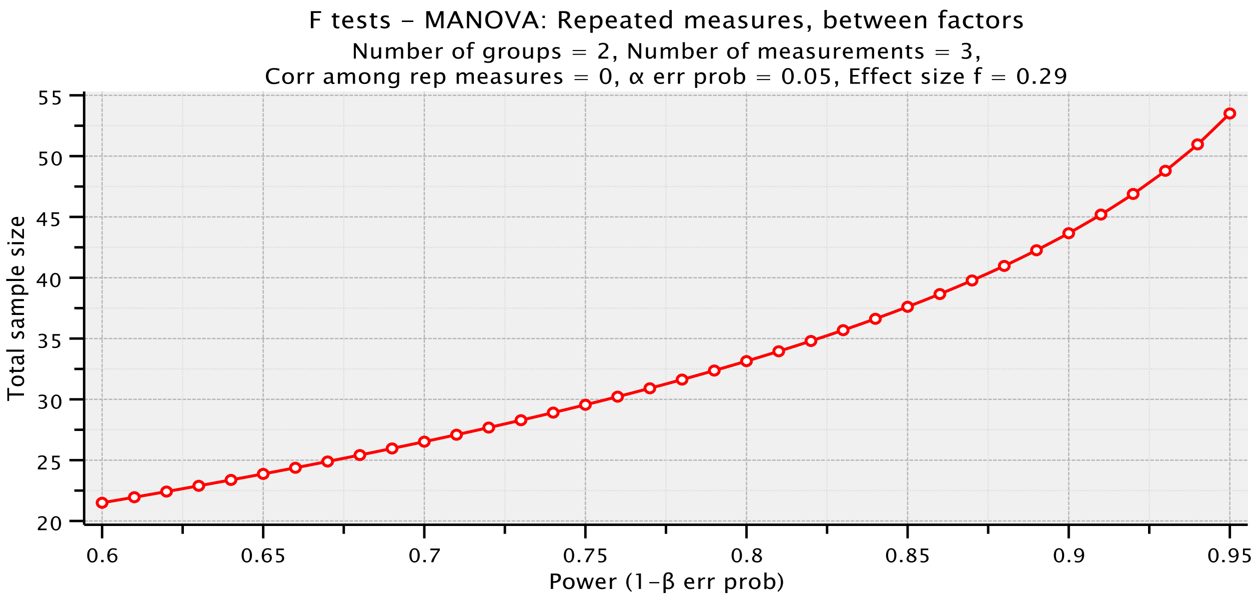

Fig. 1 Plot for sample size calculation

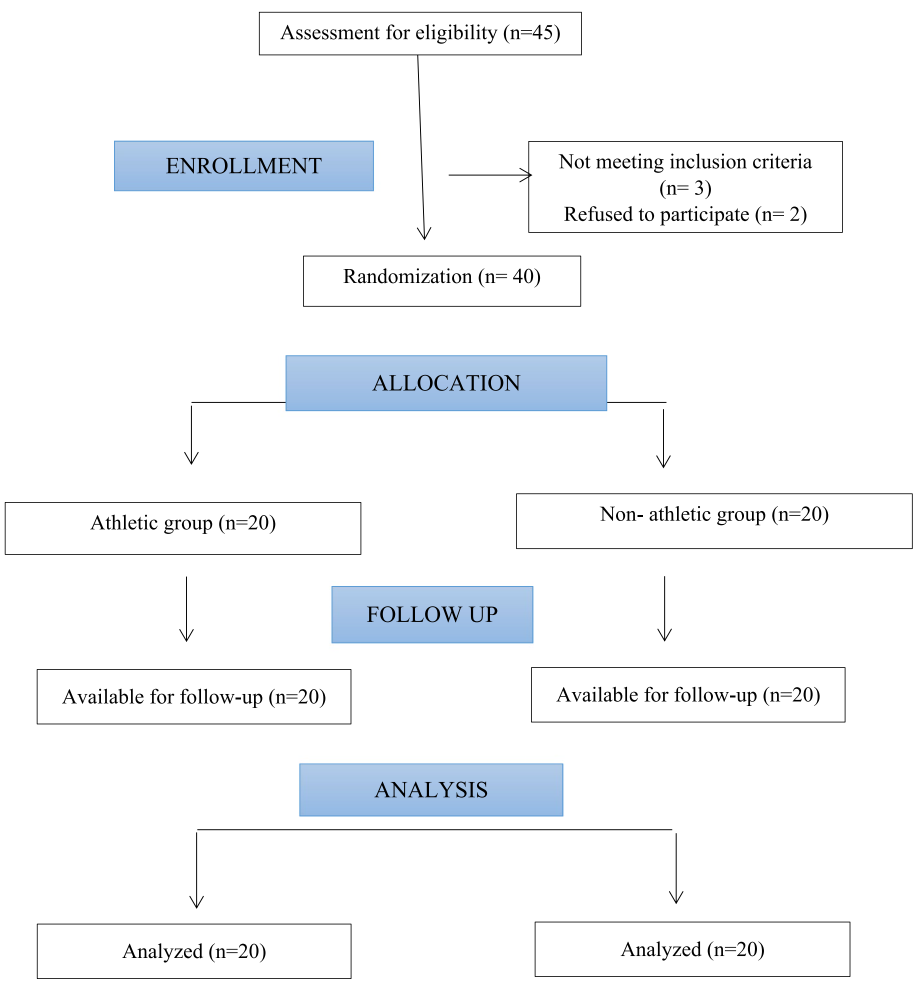

Fig. 2 Participant flow chart

based on a pilot study involving 10 participants (5 in each group).

Statistical analysis

Statistical analysis was conducted using the SPSS Package program, version 25 for Windows (SPSS, Inc., Chicago, IL). Data were assessed for normality and homogeneity of variance. Shapiro–Wilk test was performed to check the normality of the data. The Levine's test was applied to test the homogeneity of variance statistical assumption between groups, while Mauchly's sphericity assessed the homogeneity of variance within each group.

Descriptive statistics, involving means and standard deviations, were calculated for demographic data as well as grip strength, pulp pinch strength, three-finger pinch strength, and lateral pinch strength. A mixed-design MANOVA with a 2×3 factorial arrangement was employed to compare the variables of interest across the different groups (athletic group and non-athletic group) and measuring periods follicular phase, ovulatory phase, and luteal phase. A significance level of $p \leq 0.05$ was adopted for all statistical analyses to determine significant results.

Results

Table 1 represents mean ± SD of girls' baseline characteristics in athletic and non-athletic groups; there was no statistically significant difference in the mean value of age, weight, height, and BMI between the two groups.

Statistical analysis utilizing 2×3 mixed design MANOVA demonstrated a significant effect of the tested group (the first independent variable) on the dependent variables (grip strength, pulp strength, three finger strength, and pinch strength) ($F = 18.7$, $P = 0.0001$, partial eta square = 0.675). Also, there was a significant effect of the phases of menstrual cycle) the second independent variable) on the dependent variables (grip strength, pulp strength, three finger strength, and pinch strength) ($F = 21.4$, $P = 0.0001$, partial eta square = 0.843). Additionally, there was a significant interaction between the two independent variables. This suggests that the influence of the tested group (first independent variable) on the dependent variables (grip strength, pulp pinch strength, three finger strength, and pinch strength) was affected by the menstrual cycle phases (second independent variable).

Multiple pairwise comparison tests (post hoc tests) in Tables 2 and 3 revealed that there was no significant

Table 1 Comparison of baseline characteristics between athletic and non-athletic groups

	Athletic group $\bar{X}$± SD	Non-athletic group $\bar{X}$± SD	MD	t Value	*p* Value	Sig
Age (years)	18.75 ± 2.51	19.5 ± 1.85	−0.75	−1.07	0.28	**NS**
Weight (kg)	64.95 ± 5.38	63.35 ± 6.17	1.6	0.87	0.38	**NS**
Height (cm)	168.30 ± 3.49	167.35 ± 4.42	0.95	0.75	0.45	**NS**
BMI (kg/m^2)	22.63 ± 1.47	23.16 ± 2.05	−0.53	−0.92	0.36	**NS**

$\bar{X}$, mean; *BMI* Body mass index, *SD* Standard deviation, *MD* Mean difference, *t* value unpaired *t* value, *Sig* Significant, *p value* probability value, *NS* Nonsignificant

Table 2 Descriptive statistics and 2×3 mixed design MANOVA for all outcome measures during follicular, ovulatory and luteal phases

Outcomes	Phases	Athletic group	Non-athletic group	Mean differences	*p* Value
Grip strength (kg)	**Follicular phase**	31.33 ± 4.22	24.70 ± 4.63	6.63	0.0001
	Ovulatory phase	32.24 ± 3.92	28.90 ± 5.26	3.34	0.026
	Luteal phase	31.52 ± 4.37	27.00 ± 5.41	4.52	0.005
Pulp pinch strength (kg)	**Follicular phase**	6.57 ± 1.16	5.10 ± 0.78	1.47	0.0001
	Ovulatory phase	6.67 ± 1.15	5.55 ± 1.31	1.11	0.006
	Luteal phase	6.48 ± 1.12	5.10 ± 1.07	1.37	0.0001
Three finger strength (kg)	**Follicular phase**	9.81 ± 1.60	7.10 ± 1.29	2.71	0.0001
	Ovulatory phase	10.33 ± 1.46	7.55 ± 1.43	2.78	0.0001
	Luteal phase	9.81 ± 1.43	7.20 ± 1.19	2.61	0.0001
Lateral pinch strength (kg)	**Follicular phase**	11.19 ± 1.40	7.65 ± 1.38	3.54	0.0001
	Ovulatory phase	11.71 ± 1.38	8.20 ± 1.36	3.51	0.0001
	Luteal phase	11.14 ± 1.38	8.05 ± 1.35	3.09	0.0001

Table 3 Multiple pairwise comparison tests (post hoc tests) among different menstrual phases for grip strength, pinch strength, three finger, and lateral pinch strength for athletic and non-athletic group

p Value	Groups	Follicular phase vs ovulation phase	Follicular phase vs luteal phase	Ovulation phase vs luteal phase
Grip strength	Athletic group	0.05	0.999	0. 09
	Non-athletic group	0.001	0.001	0.001
Pulp pinch strength	Athletic group	0.999	0.999	0.626
	Non-athletic group	0.059	0.999	0.016
Three finger strength	Athletic group	0.006	0.999	0.002
	Non-athletic group	0.024	0.999	0.055
Lateral pinch strength	Athletic group	0.001	0.999	0.001
	Non-athletic group	0.001	0.035	0.890

p Value probability value, *SD* Standard deviation; significant at alpha level < 0.05

difference of grip strength in athletic group between (follicular phase vs. ovulatory phase), (follicular phase vs. luteal phase), and (ovulatory phase vs. luteal phase), while for the non-athletic group, there was a significant difference between (follicular phase vs. ovulatory phase), (follicular phase vs. luteal phase), and (ovulatory phase vs. luteal phase). This significant increase was in favor to ovulatory phase compared to follicular phase and luteal phase.

There was no significant difference of pulp pinch strength in athletic group, between (follicular phase vs. ovulatory phase), (follicular phase vs. luteal phase), and (ovulatory phase vs. phase III), while for the non-athletic group, there was no significant difference between (follicular phase vs. ovulatory phase) and (follicular phase vs. luteal phase) and significant difference between (ovulatory phase vs. luteal phase). This significant increase was in favor to ovulatory phase compared to luteal phase.

There was a significant difference of three finger strength in the athletic group between (follicular phase vs. ovulatory phase) and (ovulatory phase vs. luteal phase) and no significant difference between (follicular phase vs. luteal phase). This significant increase in favor to ovulatory phase was compared to (follicular phase and luteal phase), while for the non-athletic group, there was a significant difference between (follicular phase vs. ovulatory phase) and no significance difference between (follicular phase vs. luteal phase) and (ovulatory phase vs. luteal phase). This significant increase was in favor to ovulatory phase compared to follicular phase.

There was a significant difference of lateral pinch strength in athletic group between (follicular phase vs. ovulatory phase) and (ovulatory phase vs. luteal phase) and no significant difference between (follicular phase vs. luteal phase). This significant increase in lateral pinch strength was in favor to ovulatory phase compared to follicular phase and luteal phase, while for the non-athletic group, there was a significant difference between (follicular phase vs. ovulatory phase) and (follicular phase vs. luteal phase) and no significant difference between (ovulatory phase vs. luteal phase). This significant increase in lateral pinch strength was in favor to ovulatory phase compared to follicular phase.

Discussion

The fluctuating hormone levels occurring across the menstrual cycle phases can elicit alterations in muscular strength [2]. Performance of female athletes and sedentary females may be impacted by these changes [10]. This study aimed to evaluate the effect of hormonal changes on grip strength, pulp strength, three finger strength, and pinch strength through follicular, ovulation, and luteal phases in athletic and non-athletic girls.

The finding of the current study displayed no significant difference of grip strength, pulp pinch strength of athletic girls in the three menstrual cycle phases. Conversely, there was a significant difference in handgrip strength, pulp pinch strength, three fingers pinch strength, and lateral pinch strength in non-athletic girls.

The current results align with earlier research [12, 13], indicating that muscular strength, including hand grip strength and bench press strength in athletic females, exhibits non-significant fluctuations throughout the menstrual cycle. Consequently, female athletes who menstruate regularly may not feel the need to adjust their training schedules according to their menstrual cycles in order to enhance their performance. Additionally, several studies [5, 14, 15] have examined different aspects of muscular performance in active women, including handgrip strength. There were no notable alterations detected in the maximum handgrip strength throughout phases of menstrual or ovarian cycles, which corresponds with the outcomes of the present study. The outcomes of the present study align with Dasa et al. [16] who examined the menstrual cycle's influence on female strength and power performance in 29 highly trained females engaged in team athletics throughout the menstrual cycle for 6-week testing period, and they found no differences in performance during it for maximal voluntary isometric grip strength. Also, Romero et al. [17] examined the fluctuations in muscle force, velocity, and strength output in 13 females with normal menstrual cycles engaged in resistance training during three distinct menstrual cycle phases. Their findings showed that there were no regular alterations in the knee flexors' isokinetic testing and hand grip test results during the menstrual cycle.

In the same line, Arazi et al. [18] who demonstrated that muscular strength, muscle endurance, and anaerobic power in young females remain consistent across various menstrual cycle phases, but luteinizing hormone and follicular stimulating hormone levels exhibit variations during various phases. Hence, it appears that engaging in physical activity during various menstrual cycle phases does not adversely impact performance. Young females can therefore maintain their athletic activities across their menstrual cycle.

In continuation, research carried out by Gular [19] revealed no significant effects of the menstrual cycle on muscular strength, anaerobic power, or performance in volleyball athletes.

The present study showed increase in grip strength in ovulatory phase in comparison with follicular phases for non-athletic girls. These results align with Tenan et al. [4] who demonstrated a 10% increase in maximum strength for muscles of the upper limb during the ovulatory phase. Also, Phillips et al. [20] observed 10% greater strength of adductor pollicis muscles in the phases of ovulation or luteinization compared to the follicular phase.

Additionally, the study's results were consistent with Carmichael et al. [21], who measured the upper and lower body power of non-athletic subjects across three phases in two menstrual cycles.. In another study performed by Julian et al. [22], who investigated the maximum voluntary contraction of hand grip strength and found that grip strength was higher during secretory phase than proliferative and menstrual phase.

In the same line, Tenan et al. [4] observed the menstrual cycle impact on maximal isometric contraction of the upper extremity muscles and indicated that 23% decreases from the ovulatory phase to the mid-luteal phase. Another research study demonstrated that the highest strength peak was observed just prior to ovulation, particularly in the quadriceps strength and handgrip force measurement with dynamometer. This led to the conclusion that estrogen level surge prior to and during the ovulatory phase might be the underlying cause of this alteration [23].

However, these findings disagree with Pallavi et al. [2], who demonstrated a 10% increase in strength at the late follicular phase of the menstrual cycle among active women. They reported a significant difference in hand grip strength among the three menstrual cycle phases, including menstrual, late follicular, and late luteal phases. Also, Hudgens et al. [24] observed that during the late follicular phase, women exhibit superior hand steadiness compared to the luteal phase.

Moreover, other researchers mentioned that the highest peak in strength was noted immediately preceding ovulation, particularly in quadriceps strength and handgrip force measured with a dynamometer. This suggests that the surge in estrogen levels before and during the ovulatory phase may be the contributing factor to this change [20]. Friden et al. [25] found that isometric hand grip strength displayed no alterations throughout the menstrual cycle. Also, Gorden et al. [26] detected no differences between pre-menstrual and post menstrual periods in muscular strength which tested isometric quadriceps strength and hand grip strength in sedentary life women.

Conclusion

There is no impact of menstrual cycle hormones on athletic hand grip strength and pulp pinch strength, but it influences hand grip strength, pulp pinch strength, three fingers strength, and lateral pinch strength for the non-athletic group. With increasing hand grip strength, the hormonal alterations effect during menstrual cycle phases decreases. Thus, it could be concluded that hormonal alterations during menstrual cycle have more effect in grips strength of non-athletic group than athletic group.

Implication of the study

This study evaluated the effect of hormonal changes during menstrual cycle phases (follicular, ovulation, and luteal phases) on hand grip strength, pulp pinch strength, three fingers strength, and lateral pinch strength in athletic and non-athletic girls. It would help in designing not only a rehabilitation program but also prevention and treatment of any injuries in athletic girls and also encouraging non-athletic girls in participating in any sports like basketball and tennis to increase hand grip strength.

Limitations

The mood changes observed in female participants could potentially affect the results of the study. So, it would have been more appropriate to utilize an objective assessment tool, such as the visual analogue scale, to evaluate these symptoms. The study evaluated the grip strength for tennis and basketball players only and cannot be generalized to other sports. Also, the age was limited to certain age group (16 to 22 years) and cannot be generalized to all women. Additionally, fluctuations in hormones like testosterone and relaxin may have an impact on tissue properties, consequently influencing strength and power. Lastly, it would have been beneficial to objectively measure hormone levels throughout the menstrual cycle.

Recommendations

The finding of this study encourages the girls to participate in sports like tennis and basketball. Further studies are needed to investigate the effect of hormonal changes through menstrual cycle phases on different muscles of upper limb, lower limb, and core muscles. Further studies are needed to investigate the effect of hormonal changes through menstrual cycle phases on different types of sports and different age groups.

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Authors' contributions
H.A.S. was responsible for the study's conceptualization and design, data collection and interpretation, manuscript drafting, revision, and review, as well as accepting responsibility and accountability for the article's content. A.M.Y. was responsible for the study's conceptualization and design, data interpretation, manuscript revision, and review, as well as accepting responsibility and accountability for the article's content. H.A.H. was responsible for the study's conceptualization and design, supervision of data collection, manuscript revision, and critical review, as well as accepting responsibility and accountability for the article's content. E.S.H. was responsible for the study's conceptualization and design, data analysis and interpretation, manuscript revision, and review, as well as accepting responsibility and accountability for the article's content.

Availability of data and materials
Data and materials are available up on request.

Declarations

Ethics approval and consent to participate
The protocol of the study was registered in clinical trials.gov PRS (Protocol Registration and Result System (registration No.NCT06086262), Registered on 17 October 2023,https://classic.clinicaltrials.gov/ct2/show/NCT06086262. The study received ethical approval from the Institutional Review Board of the Faculty of Physical Therapy at Cairo University prior to its beginning (approval No P.T.REC/012/003358). A written informed consent was obtained from each participant and their caregivers after clarifying the study's purpose and their right to decline or withdraw from the study at any point by signing the appropriate informed consent paperwork.

Consent for publication
Not applicable.

Competing interests
Not applicable.

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