Aziz et al.
Bulletin of Faculty of Physical Therapy (2023) 28:25
https://doi.org/10.1186/s43161-023-00136-9

Bulletin of Faculty of Physical Therapy

ORIGINAL RESEARCH ARTICLE

Open Access

Effect of ovulation on postural sway in association with sex hormone variation across the menstrual cycle in college students: an observational study

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Abstract

Background Poor balance associated with increased postural sway is a risk factor for the high incidence of injuries found during specific menstrual cycle phases. This fact led to the hypothesis that female reproductive hormones affect soft tissue and neuromuscular function, reducing postural balance and resulting in a high injury prevalence among female college students. So, the current study aimed to identify the influence of ovulation in association with sex hormone variation across the menstrual cycle on postural sway in college students.

Material and methods Forty female college students were enrolled in this study. They were recruited among physical therapy students at Deraya University, New Minya, Egypt. They were aged from 17 to 22 years. They were allocated to a single group. Progesterone and estradiol blood levels were measured to detect the timing of the follicular and luteal phases, and a urine luteinizing hormone (LH) strip test was used to determine when ovulation occurred. The dynamic postural sway index was assessed by using the Biodex Balance system. All measurements were taken on the early follicular (1^{st}–3^{rd}) day, the ovulatory (11^{th}–13^{th}) day, and the mid-luteal phase (21^{st}–23^{rd}) day from the onset of menstruation.

Results Statistical analysis showed that the anteroposterior, mediolateral, and overall sway index increased significantly during the ovulatory phase compared to the earlier follicular and mid-luteal menstrual cycle phases in female college students ($P < 0.05$). There was no significant variance between the early follicular and mid-luteal phases ($P > 0.05$).

Conclusions It can be concluded that increased female sex hormones during ovulation affect postural sway, which may disturb balance and increase the risk of injuries in college students.

Keywords Menstrual cycle, Ovulation, Postural sway, Sex hormones

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Introduction

The cyclical and periodical excretion of blood and mucosal tissues via the vaginal opening from the endometrium is known as menstruation. It occurs due to variations in a female's sex hormone levels and comprises ovarian and uterine cycles. The three phases of the ovarian cycle are called follicular, ovulatory, and luteal, and each has distinctly altered sex hormone profiles [1, 2].

Estradiol and progesterone levels in the blood are typically low during the follicular period (days 2–13). Estrogen levels are raised at the late follicular phase, reaching their highest at ovulation, which is the process by which a woman with a 28-day ovarian cycle ejects an egg or oocyte from the ovary on the 14^{th} day [3]. Finally, progesterone levels are raised during the luteal phase, whereas estradiol levels stay high and gradually revert to their normal level [4, 5].

Dynamic balance is the individual's ability to retain balance while transferring from the dynamic to the static state; it necessitates a certain motion around the base of support. Several systems, including the central nervous, sensory, and motor systems, have an impact on balance [6]. Postural sway refers to the movement of the center of gravity in forward, backward, and lateral directions (i.e., during a static position, the body continually exhibits low-amplitude motions). It can be used and measured as an indicator of balance [7, 8].

Sex hormone receptors have apparently been found in various body connective tissues, such as skeletal muscles, bones, tendons, and ligaments. For this reason, estrogen fluctuation among different menstrual cycle phases alters muscle tone, tendon strength, ligament elasticity, and neuromuscular function; it also softens ligamentous collagen cross-bridges through the menses [5]. Previous studies have linked the efficacy of female reproductive hormones on soft tissues to a decrease in joint stability, which is known to be a key component of postural balance affection and an increased risk of injuries [9–11].

The increase of sex hormones at ovulation and its impact on postural sway showed a major contradiction between research. Some previous research reported no discernible difference between ovulation and other menstrual cycle phases in terms of posture sway and balance performance [12, 13]. While the majority of earlier research suggested that female sex hormones might affect ligamentous laxity and muscle coordination and that poor postural balance and greater postural sway were noticed in females at ovulation when compared with other phases of menstruation [14–16]. These conflicting findings raise the need for further research at this point. So, this study aimed to explore the efficacy of ovulation on posture sway in female college students. We hypothesized that postural sway deteriorated at the ovulatory phase as a result of sex hormone variation across the menstrual cycle.

Material and methods

This research was intended as an observational, cross-sectional, repeated measure design. The Ethical Research Committee of the Faculty of Physical Therapy at Cairo University accepted this study with approval number P.T.REC/012/003102. As well, it had a Clinical trial .gov registration (NCT05088122). The Declaration of Helsinki guidelines for the conduct of human research were followed in this study. It was carried out between November 2021 and May 2022.

Participants

The sample size was estimated using the G power program, version 3.1, Heinrich-Heine-University, Düsseldorf, Germany, based on F tests (ANOVA: repeated measure, within factors), type I error (α) = 0.05, power (1-α) error probability) = 0.95, Pillai V = 0.08, and effect size f (V) = 0.29 for the primary outcome (overall sway index), one independent variable with three levels (menstrual phases). The proper minimal sample size for this research was 32 participants. Assuming a 25% dropout, the number of participants increased to 40. The participant's selection is illustrated in (Fig. 1).

Forty college females were recruited from the Faculty of Physical Therapy students at Deraya University, New Minya, Egypt. Each female had received an informed consent form to sign after being informed of the study's initial aim and their opportunity to withdraw from the research at any moment.

The participating females should be healthy, virgin, non-athletic college students, between the ages of 17–22 years old, with a BMI ranging from 19–25 kg/m^2 to be involved in the study. Also, they should have regular menstruation with an average cycle length of 28 days. Females with irregular menstruation or who had hormonal therapy in the six months prior to the study, as were females with vestibular system problems, otitis media, or other intrinsic ear problems that may disturb the balance, or females with a history of lower limb fractures, surgeries, or feelings of ache during daily activities, were excluded from the study [17].

Assessment

Initially, a data recording sheet was given to each female student for recording data, including age, weight, height, and BMI. Then, she was instructed to complete the self-administrated questionnaire to provide information about her menstrual history in the last 6 months before the study, which comprised the age of menarche, menstrual cycle number in the previous year, the last menstrual cycle date, the average length of menstruation (3–7 days on average), regularity, frequency (28 days on average), and presence or absence of dysmenorrhea [18].

Serum estradiol (E2) and progesterone levels were measured using hormone kits (ELISA LSBIO, USA) at early follicular (days 1–3) and once more at mid-luteal (days 21–23) phases to precisely time each menstrual cycle phase. The urinary LH strip test (Oview by

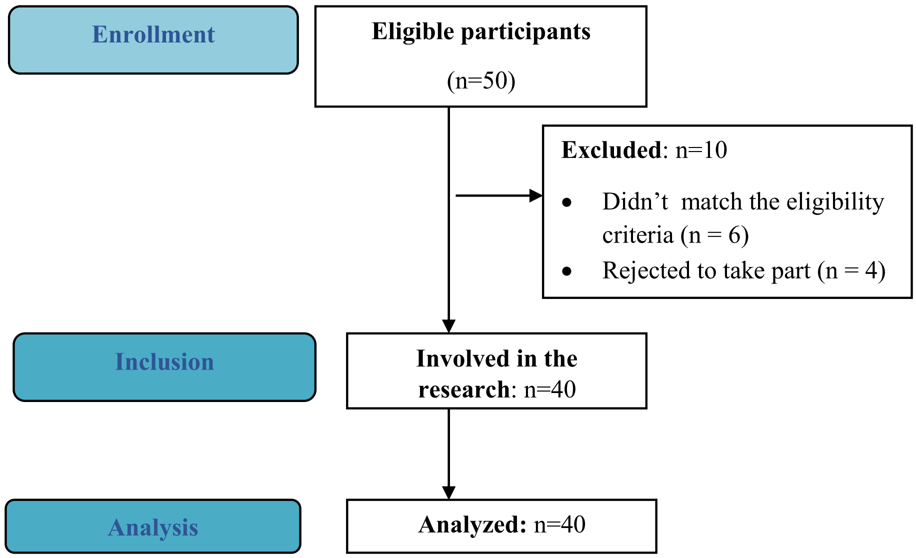

Fig. 1 Flow diagram of the study

UniComs GmbH, Switzerland) was also used to determine the precise time of ovulation. It was utilized at (11–13 days) of the period, when it was positive; the assessment procedure at the ovulatory phase was carried out [19]. It is regarded as a reliable, valid, and highly precise method of determining ovulation time [20, 21].

The Biodex balancing system SD was used to evaluate the participants' postural sway during three distinct menstrual cycle phases: early follicular (1^{st}–3^{rd} day), ovulatory (11^{th}–13^{th} day), and mid-luteal phase (21^{st}–23^{rd}).

Evaluative instrumentation

Biodex Balance System SD

The Biodex Balance System (Inc., Shirley, NY, USA) has become widely used in clinical and scientific research. It comprises a movable, multiaxial balance platform that allows a surface tilt of up to 20° throughout a 360°ROM (range of motion). The platform stability can be altered by adjusting the spring's resistance level beneath it. This device uses computerized software (Biodex, Version 3.1, Biodex Medical Systems) that allows it to be regarded as an impartial balancing evaluation. It is made up of a circular platform with the capability of moving simultaneously in the anterior–posterior and medial–lateral axes. The measurements of postural sway include overall (OA), antero-posterior (AP), and mediolateral (ML) sway levels. A high sway index value denotes an unsteady balance. The overall sway score is thought to be the most accurate predictor of the participant's postural sway [22].

Studies have shown that the Biodex balance system can accurately measure the individuals' somatic sensory, visual, and temporal contributions to their neuromuscular function in a valid, reliable, and repeated objective manner. It can also evaluate both static and dynamic balance on stable and unstable surfaces, and highly valid and reliable results are gained when stability indices are recorded by the same rater throughout the assessment of the static and dynamic stability [8, 23].

Outcome measure

Antero/posterior, medial/lateral, and overall sway indexes

The biodex balance system postural stability test provides two types of indices, stability, and sway indices. The stability index is the subjects' average position from the center or the angle of excursion of their center of mass. The stability index does not indicate the amount of a subject's postural sway; it only measures his position. To evaluate the amount that the participant swayed, one measures the standard deviation of the stability index; this is called the sway index. Three sway indexes were quantified: The Antero-posterior sway index represents the subject's postural sway in the sagittal plane. The mediolateral sway index represents the subject's postural sway in the front plane, and the overall sway index (the summation of the two previous indices) represents the subject's postural sway in all movements and directions throughout the testing. The higher the sway index, the more unsteady the individual [8].

Procedures

All the college students were arranged into one group. The evaluative measures were performed across three menstrual cycle phases (early follicular, ovulatory, and mid-luteal). A dynamic posture stability testing mode using the updated Biodex Balance System SD version was used to evaluate the postural sway of each participant. The testing parameters were adjusted to provide 20-s trials; the platform steadiness was set at 1–10 levels. Participants completed one training trial and three testing trials, each with a 10-s rest period in between. Then, the average was calculated [24, 25]. The participant was tested for dynamic postural stability while standing barefoot on a foot platform with a self-selected toe out in a comfortable position. Then, according to the grid coordinates on the device's platform, the participant's heel placement and foot angle were recorded. Participants were told not to shift their feet and to keep the platform level, steady and immobile as much as possible, gazing forward and relaxing their arms beside their bodies until all trials were completed. Each trial was conducted with the Biodex Balance System SD display screen covered to prevent visual feedback. Accordingly, for measurement purposes, overall, Anterior–posterior and medial/lateral sway indices were considered [26].

Statistical analysis

Version 22 SPSS for Windows (SPSS, Inc., Chicago, IL) was utilized to carry out the statistical analysis of this study. There was one independent variable (menstrual phases) in the current test, within-subject factor, which compromised three levels (early follicular, ovulation, and mid-luteal). The test also included three measured dependent variables (overall sway index, antero/posterior sway index, and medial/lateral sway index). Thus, repeated measure MANOVA was utilized to compare the tested variables of interest under various testing settings. The *P*-values of less than 0.05 were regarded as significant, and those of less than 0.01 as highly significant. The second aim also included an independent variable (menstrual phases) within the subject factor, compromising two levels (early follicular and mid-luteal). Additionally, it had two measured dependent variables (estradiol and progesterone). Thus, to compare the examined variables of interest under various testing settings, repeated measure MANOVA was used.

Results

The participants' demographic data

The study included forty females. The mean ± standard deviation (SD) of their ages, weights, heights, and BMI were 19.60 ± 1.37 years, 58.80 ± 4.99 kg, 162.70 ± 5.26 cm, 22.19 ± 1.30 kg/m^2, respectively.

One-way repeated measure MANOVA for estradiol and progesterone blood levels showed a statistically significant effect for menstrual cycle phases ($F = 209.633$, $P = 0.0001^*$, partial $\eta^2 = 0.917$). As well, the univariate tests showed a statistically significant difference ($p < 0.05$) for the mean value of estradiol and progesterone between the early follicular and mid-luteal phases, and this significant surge of both estradiol and progesterone levels was in favor of the mid-luteal phase in comparison to the early follicular phase (Table 1).

One-way repeated measure MANOVA for outcome measures revealed statistically significant effects for menstrual cycle phases ($F = 16.205$, $p = 0.0001^*$, partial $\eta^2 = 0.741$). As well, there was a statistically significant difference ($p < 0.05$) between different menstrual phases according to the univariate tests for the mean of all dependent variables (overall sway, antero/posterior sway, and medial/lateral sway) (Table 2). A post hoc test (Bonferroni test) revealed statistically significant differences between (early follicular versus ovulation) and (ovulation versus mid-luteal) with a *p*-value < 0.05 and that all dependent variables increased significantly in favor of the ovulatory phase when compared to the early follicular and mid-luteal phases. However, for any dependent variable, there was a non-significant variance between early follicular and mid-luteal as *p*-value > 0.05 (Table 3).

Discussion

The current study aimed to ascertain how ovulation affects female college students' postural sway. Estrogen and progesterone affect cell metabolism and collagen proliferation and play a key role in maintaining tissue integrity [5]; their levels show variations throughout the menstrual cycle; early in the follicular phase, estrogen and progesterone are low, estrogen level rises pre-ovulation and peak at ovulation then declines after ovulation and rises secondarily at the mid-luteal stage at which

Table 1 Descriptive statistics and repeated measure MANOVA for estradiol and progesterone levels in the early follicular and mid-luteal phases

Variables	Early follicular phase Mean ± SD	Mid-Luteal phase Mean ± SD	*F*-value	*P*-value
Estradiol (pg/ml)	52.45 ± 25.62	151.90 ± 50.45	167.981	0.0001*
Progesterone (pg/ml)	0.72 ± 0.34	18.88 ± 5.72	425.708	0.0001*

SD Standard deviation, *p-value*, Probability value

* Significant level is set at alpha level < 0.05

Table 2 Descriptive statistics and repeated measure MANOVA for all dependent variables (overall sway, antero/posterior sway, medio/lateral sway) at early follicular, ovulation, and mid-luteal phases

Variables	Early follicular Mean ± SD	Ovulation Mean ± SD	Mid-luteal Mean ± SD	*F*-value	*P*-value
Overall sway	1.27 ± 0.88	3.43 ± 1.56	1.56 ± 0.88	56.392	0.0001*
Antero/posterior Sway	1.04 ± 0.76	2.96 ± 1.35	1.28 ± 0.74	58.319	0.0001*
Medial/lateral Sway	0.64 ± 0.53	1.58 ± 1.05	0.82 ± 0.57	23.459	0.0001*

SD Standard deviation; *p-value*, probability value

* Significant level is set at alpha level < 0.05

Table 3 Post hoc test (Bonferroni test) for all dependent variables across three menstrual cycle phases

p-value	Early follicular Vs. ovulation	Early follicular Vs. mid-luteal	Ovulation Vs. mid-luteal
Overall Sway	0.0001*	0.345	0.0001*
Antero/posterior Sway	0.0001*	0.413	0.0001*
Medial/lateral Sway	0.0001*	0.474	0.0001*

* Significant at alpha level < 0.05

Vs versus

progesterone peaks and finally both gradually fall to baseline at the menstrual end [18]. According to the present study's findings, mid-luteal phase levels of estradiol and progesterone were significantly higher than early follicular phase levels. These findings are confirmed by Constantini et al. [4] and Khowailed et al. [5], as the obtained measures of progesterone and estradiol from the biochemical assay adhere to their typical reference limits [27, 28].

The statistically significant increase in Antero-posterior, Medio-lateral, and overall sway indices at the ovulatory phase in comparison to the early follicular and mid-luteal stages indicates that the rise in sex hormones at ovulation has an impact on dynamic postural sway measurements. Fluctuation of female sex hormones among menstrual phases that peaks at ovulation has been specifically examined regarding its efficacy on human body connective tissues such as muscles, tendons, and ligaments. The role of female sex hormones in changing the mechanical properties, strength, synthesis, and proliferation of those tissues can demonstrate the related changes in physical performance, particularly in postural stability and subsequent postural sway [14, 15].

These findings agree with Lee and Yim [14], who investigated posture sway and function of the ankle's stabilizer muscles throughout the menstrual period in young females and concluded that postural sway was significantly higher at ovulation, when estradiol concentration reaches its peak, in contrast to the follicular phase when estrogen levels are relatively low. Also, Petrofsky and Lee [16] found that the plantar fascia had greater laxity during ovulation than the early follicular phase, resulting in higher postural instability.

Furthermore, Yim et al. [15] investigated the relationship between posture sway and mechanical properties of the ankle musculature across the different menstrual phases. They revealed that during balance tests, the postural sway increased significantly during the ovulatory phase compared to the follicular phase.

Additionally, Sung and Kim [17], who showed greater postural instability and sway through ovulation than menstrual and luteal phases in healthy young females, supported the current findings. Lee et al. [11] also found that the velocity moment and the speed of postural sway increased more significantly during ovulation than in the follicular phase in healthy females.

In contrast, the current results disagree with Reschechtko et al. [29] who reported that postural sway hadn't been affected by estrogen fluctuations across various menstrual phases among two cohort females; oral contraceptive pills users and non-users. They illustrated that they might obtain different results if they had used other balance testing protocols on a larger sample size.

Also, Abt et al. [30] examined whether the variations in the concentration of sex hormones significantly changed postural stability, motor function, knee kinetics, kinematics, and strength throughout all menstrual cycle phases and found that there were no substantial variations in the measured data of balance performance between the three different menstrual cycle phases. These results might be due to the limited sample size ($n = 10$) and inadequate power associated with each variable.

Furthermore, the non-significant differences in postural sway index between the follicular and mid-luteal phases of the menstrual period in this study are related to Hahn [31], who proposed that hormonal oscillation throughout the menstruation (pre-ovulatory, that is, follicular versus post-ovulatory, that is, luteal) did not affect ankle stability or dynamic postural control.

Also, Ericksen and Gribble [12] reported that there was not a substantial difference in ankle mechanical stability or dynamic postural control either pre- or post-ovulation in their study on young, healthy females.

In contrast, the present results disagree with those of Senol et al. [25], who concluded that dynamic balance scores were significantly lower in the follicular (menstrual) phase than during other menstrual cycle phases in healthy young females and explained that results might be obtained due to the effect of pain and a higher cortisol level during the menstrual phase. However, the researchers in this study relied on a calendar rather than hormonal analysis, which could result in inaccurate detection of menstrual phases and contribute to contradictory results.

The conflicting research results regarding the relationship between reproductive hormones and postural stability performance might be due to various balancing testing procedures or methods used to detect menstrual phase timing, as some studies lack hormonal analysis or accurate, objective evaluative procedures. The results could also be affected by the rapid fluctuation of reproductive hormones occurring at any time and throughout the menstrual period.

Strengths and limitations

The current study has numerous strengthening points. The precise timing of the early follicular and mid-luteal phases was determined by analyzing blood levels of estrogen and progesterone. Additionally, the exact timing for ovulation was determined by a valid and reliable testing procedure using the luteinizing ovulatory strip test. Furthermore, using an objective instrument for evaluating dynamic postural sway is another strong point of this research. The study, however, has some limitations as the evaluative procedures may be affected by the participant's physical and psychological conditions, mood swings, and nutritional status. Also, the testing procedures were done during one menstrual cycle and on a limited sample size. As a result, it is recommended that the evaluative measures be carried out for more consecutive menstrual cycles and on a larger sample, as this may affect the results obtained. In the upcoming studies, these aspects should be considered.

Conclusion

As regards the important role of sex hormone oscillations throughout the menstrual period on a female's physical, emotional, and psychological well-being, it can be deduced that the hormonal peak at ovulation influences the posture sway. So, greater postural sway appearing at the ovulatory phase compared to the follicular and luteal phases should have been considered before planning an exercise program for female college students regarding the importance of preventive strategies to minimize the hazards of falls and injuries.

Abbreviations

LH	Luteinizing hormone
BMI	Body mass index
E2	Estradiol
SD	Standard deviation
Vs.	Versus

Acknowledgements

The study's female participants are all gratefully acknowledged by the authors.

Authors' contributions

HA-A, KA-A, and ME-S contributed to the idea, study design, collecting data, statistical analysis, and data interpretation. All the authors cooperated with each other in writing and revising the study; they all reviewed and approved the final manuscript before it was published.

Funding

The authors did not receive any external funding for this research.

Availability of data and materials

The authors are willing to provide raw data which supports the findings of this work upon request without unnecessary restrictions.

Declarations

Ethics approval and consent to participate

This research was intended as an observational, cross-sectional repeated measure design. The Ethical Research Committee of the Faculty of Physical Therapy at Cairo University accepted this study with approval number P.T.REC/012/003102. As well, it had a Clinical trial.gov registration (NCT05088122).

Forty college females were recruited from the Faculty of Physical Therapy students at Deraya University. Each female had received an informed consent form to sign after being informed of the study's initial aim and their opportunity to withdraw from the research at any moment.

Competing interests

There is no conflict of interest among the authors.

Received: 17 March 2023 Accepted: 16 June 2023
Published online: 12 July 2023

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