Hormonal Effect Of Different Phases Of Menstrual Cycle On Postural Stability In Postpubertal Females: A Cross Sectional Repeated Measure Design

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ABSTRACT

Background: High rate of injuries detected during certain periods of menstrual cycle, raised the suggestion of the efficacy of the female sex hormones on soft tissue and neuromuscular control with subsequent deterioration of postural stability and high injury prevalence in post pubertal females. Aim of the study: The aim of the present study was to investigate the effect of female sex hormones across different menstrual phases on postural stability in postpubertal females. Participants and methods: Thirty-six postpubertal females participated in this study. They were selected from students and graduates of faculty of physical therapy, Deraya university, their age ranged from 16-25 years and their BMI was 18-27 kg/m2, they were assigned into one group. Level of serum estradiol and progesterone hormones was assessed, also timing of ovulation was detected using urine luteinizing strip tests. Biodex Balance system was used to assess dynamic postural stability index. Measurements were taken at early follicular (1st-3rd) days after menstruation, ovulation (11th-13th) day from onset of menstruation and mid luteal phase (21th-23th) days of the menstrual cycle. Results: There was a significant increase in anteroposterior, mediolateral and overall stability index at ovulation phase in compared to early follicular and mid luteal phases of menstrual cycle in postpubertal females (P<0.05) while there was non significance difference between the early follicular and the mid luteal phase P>0.05. Conclusion: Hormonal changes during different menstrual cycle phases affect the postural stability performance in postpubertal females.

Keywords: Sex hormones, Postural stability, Menstrual cycle.

I-INTRODUCTION

Menstruation is cyclic and regular discharge of blood and mucosal tissues from the inner lining of the uterus through the vaginal opening [1]. Each menstrual cycle can be divided into ovarian cycle and uterine cycle. The ovarian cycle consists of three phases; follicular phase, ovulation, and luteal phase [2].

The follicular phase is divided into two phases, the early-follicular phase (days 2-9) and the late-follicular phase (days 9-13). A female with a 28-days ovarian cycle will eject an immature ovum from one ovary on day 14 in a process called ovulation. Finally, the luteal phase starts from ovulation until the onset of another menses and it can be divided into mid-luteal (days 18-24) and late-luteal (days 25-28) phase [3].

Serum estrogen concentration fluctuates continuously throughout the normal menstrual cycle. Early follicular phase characterized by low serum levels of both estrogen and progesterone, estrogen is elevated in the late follicular phase reaching its peak at ovulation, progesterone is elevated during the luteal phase while estrogen remains elevated and slowly returns to baseline level [4,5].

Estrogen alpha and beta receptors have been reported to be present in skeletal muscles, tendons and ligaments that’s why estrogen fluctuation altering muscle function, tendon, ligament strength, neuromuscular control and relaxes collagen cross bridges in ligaments during the menstrual cycle [5]. This hormonal effect on
soft tissues is accompanied by the loss of joint stability known to be an important factor for postural stability and injury development [6].

Postural stability is the ability to maintain equilibrium by keeping the center of pressure within the support base [7]. It has two types, static and dynamic. Static balance is maintaining body equilibrium in static positions, while dynamic balance is keeping one’s equilibrium during motion or while changing from one position to another [8].

Balance is affected by various systems such as the sensory, motor, and central nervous systems. Since the receptors of sex hormones are found in bone, skeletal muscle, ligaments, and the nervous system, so, the fluctuation of estrogen and progesterone between different menstrual cycle phases influences the neuromuscular control resulting in balance affection [9, 10].

The hormonal oscillation across menstrual cycle and its effect on postural stability revealed a major contrast among the studies. Some previous studies suggested that there was no significant difference in the balance performance between the premenstrual (non-cyclic) and menstrual cycle phases [11,12]. While most previous studies reported that sex hormones might have an impact on both ligamentous laxity, muscular coordination and that there was poor postural stability in females during preovulatory stage compared to postovulatory stage of the menstrual cycle [13, 14, 15]. These contradictory results raising the need of further researches at this point. So, the aim of this study was to investigate the hormonal effect of different menstrual phases on postural stability in post pubertal females.

II- PARTICIPANTS & METHODS

• Study Design:

This was a cross-sectional repeated measure study, it was approved by the Ethical Research Committee, Faculty of Physical Therapy, Cairo University (No: P.T.REC/012/003102). Also, it was registered at clinical trial.gov. (NCT05088122). This study followed the guidelines of Declaration of Helsinki on the conduct of human research. It was conducted from February 2021 until July 2021.

• Participants:

Thirty-six post-pubertal females participated in this study, they were recruited from students and graduates of Faculty of Physical Therapy, Deraya University. An informed consent was given to each female after explaining the initial purpose of the study and their right to refuse or decline from the study at any time.

• Eligibility criteria:

To be included in the study, the participants should be virginal, healthy, non-athletic post-pubertal females, their age ranged from 16-25 years, their BMI ranged from 18-27 kg/m2 and they had regular menstrual cycle. And they were excluded from the study if they had menstrual irregularity, history of using oral contraceptives or any hormonal treatment in the previous six months before participation in the study, history of lower extremity injury, surgery or pain during activities of daily living (ADL) and females having any vestibular problems, otitis media, labyrinthitis or any inner ear problems that can affect the balance [16].

• Assessment:

Initially, the participants data including age, weight and BMI were collected from all females. They were asked to fill self-administrated questionnaire to identify their menstrual history which included menarche age, number of menstrual cycles in the last year, date of the last menstrual cycle, menstrual cycle length (3-7 days), frequency (28-35 day), regularity, pain and use of analgesics or antispasmodics during menstruation [17].

The timing of each menstrual phase was detected through measuring serum estradiol(E2) and progesterone level by hormonal kits (ELISA LSBIO, USA) at early follicular phase (day1-3) and again at midluteal phase (day21-23), also, ovulation was confirmed by using the luteinizing hormone ovulatory strip test (Oview by UniComs GmbH, Switzerland) for exact detection of ovulation. It is considered as reliable and highly accurate method for ovulation detection [18,19]. It was used at (11th-13th) day of the menstrual cycle, when the test was positive, the evaluative procedure was performed at ovulatory phase.
Dynamic postural stability was evaluated throughout the menstrual cycle (early follicular (day1-3), ovulation (day11-13) and midluteal phase (day21-23) for all participants by the Biodex balance system SD.

**• Instrumentations:**

**Biodex Balance System SD:**

Biodex Medical Systems (Inc., Shirley, NY, USA) is a multiaxial platform system used in both clinical and research settings on which the stability of the platform can be changed by adjusting the level of the springs resistance that located below it. It uses a circular platform which has the ability to move in the anterior-posterior and medial-lateral axes simultaneously. The degree of surface instability is controlled by the system’s microprocessor-based actuator. It consists of adjustable support rails that can swing away from platform when not in use, foot platform which can tilt 20 degrees from horizontal in all directions, color touch-screen display that has viewing area: (168 x 127 mm) with resolution: 800 pixels x 600 pixels and printer HP rested on printer stand. Participant’s capacity of the device is up to 400 lb (136 kg) weight [20].

Several researches suggested that the Biodex balance system provides a valid, reliable, and repeatable objective measurements of the contribution of an individual’s somatosensory, visual and vestibular to their neuromuscular control as well as its ability to assess postural stability on both stable (static) or unstable (dynamic) surfaces and that the stability indexes produced from it are valid and reliable when they are scored by a single rater during static and dynamic balance assessment [21,22].

**• Outcome measures:**

**Anteroposterior, Mediolateral, and Overall stability indexes:**

The stability index is the angular excursion of the participant’s center of gravity (ie: the individual’s average position from the center). Three stability indices were calculated as follows: antero-posterior stability index represented the variance of foot platform displacement in degrees from neutral level for motion in the sagittal plane. Mediolateral stability index represented the variance of foot platform displacement in degrees from neutral level for motion in the frontal plane and overall stability index (sum of the first two indexes) represented the variance of foot platform displacement in degrees in all motions and directions during the test [23].

**• Procedures:**

All participants were arranged in one group, dynamic postural stability of each participant was evaluated with dynamic postural stability test mode using the revised version of the biodex balance system SD, with the platform stability set at level (1-10). The test parameter was customized to allow for 20-second trials. Participants performed 1 practice trial and 3 test trials then the average was calculated. Ten seconds of rest were allowed between each trial [24,25,26]. Dynamic postural stability test was performed while the female stood barefoot on foot-platform in a comfortable position. A self-selected (comfortable) toe out was allowed. After participants were positioned, they were instructed not to move their foot until all trials were completed. The tester then entered participants’ heel position and foot angle according to the grid coordinates on the biodex balance system SD platform. Participants were instructed to maintain the platform at level, stable and motionless as possible while looking straight forward and maintaining their arms relaxed beside the body throughout the entire trial. The Biodex Balance System SD display screen was covered during each trial, so the visual feedback regarding the platform orientation was unavailable. As a result, overall stability, anterior–posterior, and mediolateral indexes were taken into account for measurement purposes. For these indexes, a low value indicated high stability and vice versa. These testing measurements was applied throughout three different menstrual phases (early follicular, ovulation and mid-luteal) [27].

**Sample size estimation:**

Before the study, the number of patients required for the study was determined after a power calculation according to data obtained from previous study [16]. In that study the mean of limits of stability (LOS) at early follicular and ovulation was 55.4±14.63 and 61.44±14.43 respectively. Sample size estimation was performed
utilizing G Power statistically programming (version 3.1 9.2 software) \([\alpha=0.05,\ \text{power}=80\%\ \text{and}\ \text{Effect size} =0.516]\) at the level of 0.05 significance and indicated that the proper sample size for this study was \([N=32]\). We collected larger number than the calculated sample size to overcome missing of participants which might occur.

**Statistical analysis:**

Statistical analysis was conducted using SPSS for windows, version 22 (SPSS, Inc., Chicago, IL). The current test involved one independent variable was the (menstrual phases); within subject factor which had three levels (Early Follicular, Ovulation, and Mid Luteal). In addition, this test involved three tested dependent variables (Overall stability index, Anteroposterior stability index, mediolateral stability index). Accordingly, repeated measure MANOVA was used to compare the tested variables of interest at different tested conditions. P-value less than 0.05 was considered significant and less than 0.01 was considered highly significant.

**III- RESULTS**

Of the initial 43 participants, four of them did not follow the inclusion criteria as they had irregular menstrual cycle, previous lower limb operation which would affect the testing procedure and its results. Another three refused to participate in the study because of personal reasons. So, only thirty-six participants were included and analyzed (Figure 1).

**The participants’ demographic data:**

Thirty-six females participated in the study. Their mean ± standard deviation for age, weight, height, and BMI were 23.75±1.46 years, 59.08±4.79 kg, 162.25±5.25 cm, 22.42±1.16 kg/m2 respectively.

One way repeated measure MANOVA for serum estradiol and progesterone indicate a statistically significant effects for phases of menstrual cycle (F=164.85, P=0.0001*). Also, the univariate tests for the mean of serum estradiol between (early follicular Vs. mid luteal) showed a highly statistically significant difference (p0.0001*) and this significant increase in serum estradiol and progesterone in favour to mid luteal phase in compared to early follicular (table 1).
One way repeated measure MANOVA for outcome measures indicate a statistically significant effects for phases of menstrual cycle (F= 7.741, p= 0.0001*, Partial η2= 0.608). Also, the univariate tests for the mean of all dependent variables (overall stability index, anteroposterior stability index, mediolateral stability index) among different menstrual phases showed a statistically significant difference (p<0.05). A bonferroni multiple comparison tests (post hoc tests) revealed that there were significant differences between (early follicular Vs. ovulation) and (ovulation Vs. mid luteal) with (p-value<0.05) and this significant increase in all dependent variables in favour to ovulation phase in compared to early follicular and mid luteal phases. While there was no significant difference between (early follicular Vs. mid luteal) with (p-value>0.05) for all dependent variables (table 2).

Table (1). Descriptive statistics and repeated measure MANOVA for Serum estradiol and progestrone between different menstrual phases.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean±SD Early Follicular phase</th>
<th>Mean±SD Mid Luteal phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum estradiol (pg/ml)</td>
<td>52.13±25.3</td>
<td>152.72±48.81</td>
</tr>
<tr>
<td>Serum progesterone (pg/ml)</td>
<td>0.70±0.34</td>
<td>18.2±5.9</td>
</tr>
</tbody>
</table>

The univariate tests for the mean of Serum estradiol between different menstrual phases

<table>
<thead>
<tr>
<th>Variables</th>
<th>F-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum estradiol (pg/ml)</td>
<td>161.425</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Serum progesterone (pg/ml)</td>
<td>334.884</td>
<td>0.0001*</td>
</tr>
</tbody>
</table>

*Significant level is set at alpha level <0.05
SD: standard deviation

Table (2). Descriptive statistics for all variables (Overall stability index, Anteroposterior stability index, mediolateral stability index) at early follicular, ovulatory and mid-luteal phases.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Early follicular (phase I)</th>
<th>Ovulatory (phase II)</th>
<th>Mid-luteal (phase III)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall stability index</td>
<td>1.68±0.5</td>
<td>3.10±1.4</td>
<td>1.87±0.58</td>
</tr>
<tr>
<td>Anteroposterior stability index</td>
<td>1.55±0.47</td>
<td>2.84±1.34</td>
<td>1.73±0.53</td>
</tr>
<tr>
<td>Mediolateral stability index</td>
<td>0.44±0.2</td>
<td>0.88±0.5</td>
<td>0.51±0.22</td>
</tr>
</tbody>
</table>

The univariate tests for the mean of all dependent variables among different menstrual phases

<table>
<thead>
<tr>
<th>Variables</th>
<th>F-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall stability index</td>
<td>31.612</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Anteroposterior stability index</td>
<td>28.555</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Mediolateral stability index</td>
<td>17.921</td>
<td>0.0001*</td>
</tr>
</tbody>
</table>

Bonferroni multiple comparison tests (Post hoc tests) for all dependent variables among three phases of menstrual cycle

<table>
<thead>
<tr>
<th>p-value</th>
<th>Phase I Vs. phase II</th>
<th>phase I Vs. phase III</th>
<th>phase II Vs. phase III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall stability index</td>
<td>0.0001*</td>
<td>0.412</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Anteroposterior stability index</td>
<td>0.0001*</td>
<td>0.362</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Mediolateral stability index</td>
<td>0.0001*</td>
<td>0.661</td>
<td>0.0001*</td>
</tr>
</tbody>
</table>

Significant at alpha level < 0.05, Phase I: Early follicular; Phase II: Ovulatory; Phase III: Mid-luteal; Vs: Versus.

IV- DISCUSSION
Changes of female sex hormones, regulating menstrual cycle, have subsequent impact on physical condition through acting on thermoregulation, circulatory and respiratory functions, muscles and ligaments functions, neuromuscular control and fluid metabolism. So, changes in the profile of female’s sex hormones allow suggestion of corresponding changes in physical fitness performance, including postural stability [28]. The aim of the present study was to investigate the hormonal effect of different phases of menstrual cycle on postural stability in post pubertal females.

The results of the current study suggested that there was a significant difference in serum estradiol and progesterone between early follicular and mid luteal phase (ie: significant increase in serum estradiol and progesterone during mid luteal phase in compared to early follicular phase. These results are supported by Constantini et al. and khournals et al. [4,5] as the values of estrogen and progesterone obtained from hormonal analysis accommodate to their normal reference ranges [29,30].

These hormonal fluctuations among different menstrual phases resulted in differences in dynamic postural stability measurements as the current result showed that there was significant increase in anteroposterior, mediolateral and overall stability indexes during ovulation compared with early follicular and mid luteal phase of menstrual cycle.

The current results agree with Lee et al, who found that there was a significant increase in the velocity moment and speed which indicates poor postural stability at ovulation compared to the beginning of menstruation [31]. Also, the current findings are confirmed by Sung and Kim, who investigated the influence of ovulation on postural stability in young female and proved that postural instability increased during ovulatory phase of menstrual cycle in compared to menstruation and luteal phase in healthy female [16].

The results of this study are also supported by Petrofsky and Lee, who suggested that plantar fascia laxity was greater at ovulation compared with early follicular in women and women’s postural instability and tremor were greater at ovulation, when plantar fascia laxity was increased, than during early follicular [32].

Also, the results of this study are in line with Shahin et al., who analyzed postural balance during different stages of menstrual period and its association with body composition parameters in young female students, with the aim to define pre- and postovulatory balance differences in them and proved that there was poor postural balance in females during preovulatory stage compared to postovulatory stage of the menstrual cycle [33].

In contrast, the results of this study are in disagreement with Ericksen and Gribble, who carried out a study on twenty healthy women subjects for investigation of dynamic postural stability and ankle stability and concluded that both ankle mechanical stability and dynamic postural control remained consistent before and after ovulation in women with no significant difference [11]. Also, the current findings are opposed by Sedef et al., who conducted a study which was followed balance performance in menstrual and premenstrual phases for 4 months, and concluded that there were no significant differences in the balance performance between the phases of the menstrual cycle and premenstrual (non-cyclic) period [34].

Strengths and limitations:

The present study has several strengthening points. Hormonal analysis of estrogen and progesterone was used to determine actual timing of early follicular and mid luteal phases. Also, luteinizing ovulatory strip test was used to define exact timing of ovulation for accurate testing procedures. Moreover, objective method used for dynamic postural stability assessment is an additional strength of this study. However, there are some limitations in this study. First, testing procedures were performed across one menstrual cycle, so, the evaluation performed for more consecutive menstrual cycles is recommended as it may provide different outcomes. Secondly, personal and individual differences between participants, psychological, physical and nutritional status and mood changes of participants may affect evaluation stage. Finally, the fluctuation of other hormones, such as relaxin and testosterone, may also influence tissue properties and may affect the outcomes of the study. So, further researches are warranted to investigate the impact of these hormones on postural stability.

V- CONCLUSION

It can be concluded that postural stability affected by hormonal oscillation occurred throughout menstrual cycle, higher postural instability during ovulation compared to follicular and luteal phases should be taken into consideration when designing training programs for postpubertal females concerning on the role of prevention strategies to decrease the risk of fall and injury.

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www.turkphysiotherrehabil.org
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Conflict of interest: The authors have no conflict of interest.

REFERENCES