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Comparative Study on the Duration of Voluntary Apnea in the Follicular and Luteal Phase of the Menstrual Cycle

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ABSTRACT

In the last decades, there has been a significant rise in the number of women participating in activities that require hold of breath for a long time both at a recreational and professional level. During a normal menstrual cycle, wide fluctuation in estrogen and progesterone levels is observed. In particular, it is known that estrogen and progesterone stimulate pulmonary ventilation. This study was aimed at determining the effect of menstrual cycle on the duration of voluntary apnea. 20 healthy young female subjects were used for this study. They were divided into 2 groups of 10 subjects each. Group A; those in follicular phase. Group B; those in luteal phase. Total of three maximal repeated BH efforts were performed and with a 1-min interval between efforts. All apneas were terminated at the maximum individual breaking point. Data was analyzed using graph pad prism version (8.1) and relevant statistical values were obtained. Data obtained from the analysis were presented as Mean \pm SEM. Values of $P < 0.005$ were considered significant. Values of apnea for follicular phase was 31.62 ± 2.026 and that of luteal phase was 47.08 ± 2.931 . The duration of voluntary apnea intensified during the luteal phase which may be due to hormonal variations that occur at the phase of the menstrual cycle.

Keywords: Female Reproductive System, Menstrual Cycle, Follicular Phase, Luteal Phase, Voluntary apnea.

INTRODUCTION

The female reproductive system, unlike men, shows regular cyclic changes that may be regarded as periodic preparation for pregnancy and fertilization. In primates and humans, the cycle is a menstrual cycle, and its most conspicuous feature is the periodic vaginal bleeding that occurs with the shedding of uterine mucosa (menstruation). The length of the cycle is notoriously variable, but an average figure is 28 days from the start of one menstrual period to the start of next. By common usage, the days of the cycle are identified by number starting with the first days of menstruation. It begins at puberty, ranging from the ages of 10 to 16, and ends at menopause at an average age of 51 [1]. Hormones are secreted in a negative and positive feedback manner to control the menstrual cycle. Hormone secretion begins in the hypothalamus where gonadotropin-releasing hormone (GnRH) is secreted in an increased, pulsatile fashion once puberty starts. This feedback mechanism is controlled by up-regulating, to increase hormone production, or down-regulating to decrease hormone production, the GnRH receptors on the anterior pituitary [2].

Apnea is the cessation of breathing. During apnea, there is no movement of the muscles of inhalation, and the volume of the lungs initially remains unchanged [3]. The effect of gender has been studied and no significant difference was found in BHT between males and females [4]. In the last decades, there has been a significant rise in the number of women participating in activities that require hold of breath for a long time both at a recreational and a professional level. According to the International Association for the Development of Apnea (AIDA) women's participation in static apnea reached to 289 in 2017, whereas there was a single participation of woman in 1998, with breath-hold time (BHT) ranging from 57 s to 420 s [5]. It has been shown that breath-hold (BH) ability is mostly affected by ventilatory response to hypercapnia and hypoxia [6], metabolic rate [7], magnitude of diving response [8] and BH experience [9].

It is important to consider whether the cyclic variations of estrogen and progesterone levels can impact outcome measures when conducting studies in women. In the aforementioned study, all female subjects performed breath hold (BH) in the follicular phase of their menstrual cycle. During a normal menstrual cycle, wide fluctuation in estrogen and progesterone levels is observed [10]; [11]. These cyclic hormonal variations during the menstrual cycle have been shown to affect

ventilatory, cardiovascular and autonomic nervous system responses. In particular, it is known that estrogen and progesterone stimulate pulmonary ventilation [12]; [13]. Ventilatory responses to hypoxia and hypercapnia have been reported to be elevated during the luteal compared with the follicular phase of menstrual cycle in several studies [14]. In addition, resting and maximal exercise minute ventilation increase in the luteal phase (days 17–27 of menstrual cycle) when the circulating estrogen and progesterone levels are elevated compared to the follicular phase (first 4–13 days after the onset of menstruation) when the circulating estrogen and progesterone levels are lower. Due to stimulation of ventilation in L phase the partial pressures of alveolar and arterial carbon dioxide at rest have been shown to be lower in this phase of menstrual cycle [15]; [16].

Respiratory function (i.e. lung volumes and capacities) is not influenced by ovarian hormones [17]. However, lung diffusion capacity varies across the menstrual cycle, reaching a nadir during the follicular phase and increasing during the luteal phase [18]. Cardiovascular autonomic function is modified during regular menstrual cycle. It seems that parasympathetic and sympathetic activity is influenced by estrogen and progesterone. As such, parasympathetic activity is elevated during the follicular phase [19], while sympathetic activity is greater during luteal phase of menstrual cycle [20]. The above fluctuations in the physiological responses according to variations of ovarian hormones are possible to influence the BH ability. Although it is well known that the fluctuation level of ovarian hormones affects ventilatory, cardiovascular and autonomic nervous system responses. Thus, the study is designed to examine whether the breath-hold ability would be different across a regular menstrual cycle.

MATERIALS AND METHOD

Research Centre and Period: This research was conducted in different Departments and Faculties of University of Benin, Benin city in Ovia North East Local Government Area of Edo State, Nigeria between May 2021 and June 2021.

Research Design: The study was carried out using: An Open ended questionnaire, covering bio-data and other relevant information. They were directly administered to subject participants.

Subjects: Sixteen healthy females, aged 21 ± 3 yrs. (mean \pm SD), body mass 56.4 ± 6.8 kg volunteered to participate in the present study. All subjects were students at the University of Benin, Benin city. They are nonsmokers and inexperienced in BH activities. All females had regular menstrual cycles lasting 24–31 days, had no history of menstrual distress and had not utilized any form of hormonal contraception for a period of at least 6 months before the study. None was pregnant and none had been pregnant for at least 3 yrs. before starting the study. Before testing, all subjects refrained from any meal for at least 2h and from caffeine-containing beverages. Experimental procedures had the approval of College of Medical Sciences Ethics Committee, University of Benin.

Sample Collection (Hormonal Assay): The subjects were seated in a relaxed position with a tourniquet tightly placed on the arm closed to the elbow. A methylated spirit was used to clean the skin surface, and a 5ml syringe was used to puncture a vein and 5ml of blood was drawn out. A dry cotton wool was then placed over the surface of the punctured vein to stop the bleeding, and the blood sample was transferred immediately into the plain sample bottles. The blood sample was then analyzed in the chemical pathology laboratory of the University of Benin Teaching Hospital.

Method of Analysis: The blood sample was taken to the chemical pathology laboratory of the University of Benin Teaching Hospital where immunoassay tests were done. Competitive Enzyme Immunoassay (TYPE 7) was used for testing the concentration of progesterone and Delayed Competitive Enzyme Immunoassay (TYPE 9) was used to test for the concentration of estrogen.

Determination of Menstrual Cycle Phase: Menstrual cycle period was determined according to each participant's menstrual diary over the preceding 3 months. Menstrual cycle length was calculated from the first day of menses (day 1) to the day preceding the next menses. Evidence of both follicular phase and luteal phase was gotten by collecting blood samples for each time of phase. The blood was collected from the antecubital vein. Each sample was collected into tubes containing EDTA, they are then placed in a plain container and stored at -4°C freezer until assays were performed.

Experimental Procedures: On separate days, subjects performed a BH protocol in two different phases of menstrual cycle; first during follicular phase when estrogen and progesterone concentrations are low and then during luteal phase when both estrogen and progesterone concentrations are elevated. All the experiments were carried out at the same time of day for each subject (8.00–12.00). Total of three maximal repeated BH efforts were performed and with a 1-min interval between efforts, subjects were not allowed to swallow or exhale during apneas. All apneas were terminated at the maximum individual breaking point.

Statistical Analysis: Data were analyzed using graph pad prism version (8.1) and result are presented as standard error of mean \pm SEM and $P < 0.05$ was considered significant. Analysis was done using unpaired t-test to compare the mean of experiment.

RESULTS

Table 1: Comparing the values of duration of voluntary apnea and some hormonal changes during menstrual cycle.

Parameters	Follicular phase	Luteal phase	p-values
Estrogen (pg/ml)	74.78 ± 8.08	157.8 ± 27.68	0.0138
Progesterone (ng/ml)	3.430 ± 1.874	10.87 ± 2.57	0.0310

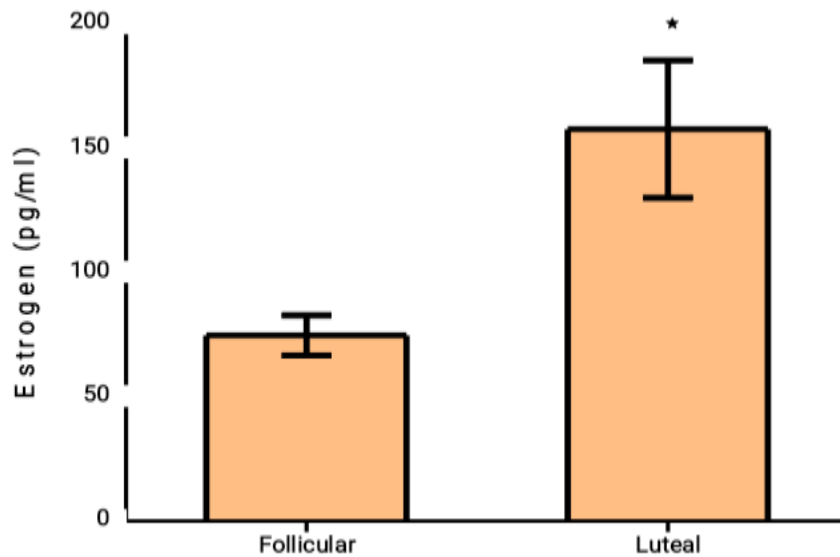


Fig. 1: Showed Estrogen level during follicular and luteal phase of menstrual cycle. There was a significant increase at luteal phase compared with follicular phase.

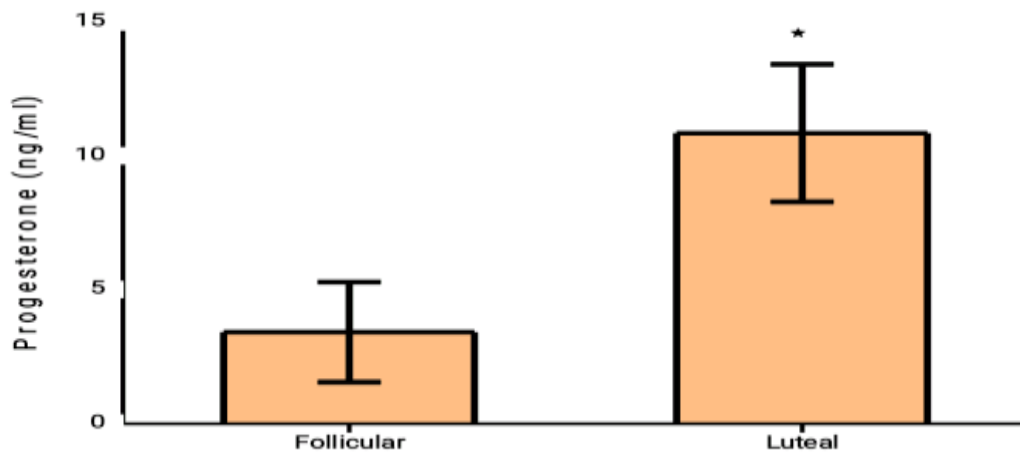


Fig 2: Showed progesterone level during follicular and luteal phase of menstrual cycle. There was a significant increase at luteal phase compared with follicular phase.

Table 2: Duration (sec) of voluntary apnea expressed as mean ± SEM during follicular phase and luteal phase of menstrual cycle.

S/N	FOLLICULAR PHASE	LUTEAL PHASE	P VALUE
1	31.62±2.026	47.08±2.931	*** 0.0001

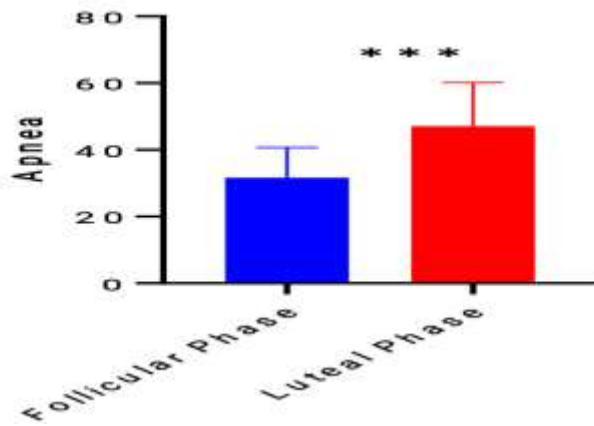


Fig. 3: Comparison of duration of voluntary apnea during follicular phase and luteal phase of menstrual cycle.

DURATION OF VOLUNTARY APNEA RESULT INTERPRETATION

(A) Mean Value of Voluntary Apnea Duration

Table 2: It shows the duration of voluntary apnea during follicular and luteal phase of menstrual cycle. Apnea duration increased significantly during luteal phase compare to follicular phase ($p < 0.05$). Higher duration was observed during luteal phase with mean \pm SEM of 47.08 ± 2.931 and lower at follicular phase with mean \pm SEM of 31.62 ± 2.026 .

(B) Comparison of Voluntary Apnea Duration During Follicular Phase And Luteal Phase

Figure 3: shows comparison of the duration of voluntary apnea during follicular phase and luteal phase of menstrual cycle. Duration of voluntary apnea increase significantly during the luteal phase compared to follicular. The p-value was 0.0001.

DISCUSSION

Voluntary apnea or breath hold (BH) ability is an activity that acutely stresses cardiovascular and respiratory systems in order to prolong the time period before the lack of oxygen becomes dangerous for the human survival [21]. This research showed an increase in the duration of voluntary apnea. This could be due to the presence of progesterone, which has been documented to stimulate pulmonary ventilation [22]. Also according to [15], ventilation is higher at rest in the luteal phase than in the follicular phase of menstrual cycle. Due to a reduction in the end-tidal PCO_2 , this further confirms the findings in this research.

CONCLUSION

This research has shown that duration of voluntary apnea varies with different phases of the menstrual cycle, which could be due to hormonal variation.

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