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Original Article

Exploring psychophysiological stress variability across menstrual phases: insights from a tertiary care centre in eastern Uttar Pradesh

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Abstract: Objectives: The menstrual cycle is the primary biological rhythm orchestrated by the hypothalamic-pituitary-ovarian axis, subject to complex hormonal fluctuations. These hormonal changes modulate cardiovascular activity, changes in heart rate variability, blood pressure, and psychological states. They often appear as premenstrual syndrome in the luteal phase. Previous studies suggested that stress reactivity is different across menstrual stages but inconsistently. For the present study, we aimed to explore psychophysiological stress reactivity following the follicular and luteal phases of the menstrual cycle in women aged 18 to 30 years. Methods: Several menstrual phases were assessed by luteinizing hormone test. All participants underwent laboratory studies in the follicular and luteal stages as follows: basal blood pressure and heart rate measurements were taken, whereas psychological stress was measured with the State-Trait Anxiety Inventory (STAI). Stress responses were elicited using the cold pressor test, and data were quantified using paired t-test and correlation analyses. Results: Upon analysing the results, it was found that basal blood pressure and heart rate were not significantly different between the three phases. However, diastolic blood pressure rose considerably during the luteal phase following the cold pressor test. Trait anxiety scores were significantly increased during the luteal phase, and significant differences in state anxiety were detected only after the stressor in this phase. Conclusions: These findings indicated that the luteal phase could reflect maladaptive psychophysiological stress reactivity. Taken in aggregate, the findings highlight the relevance of menstrual cycle phases in stress assessments and treatment interventions, promoting individualized methods in women's healthcare.

Keywords: Stress reactivity, psychophysiological changes, menstrual cycle, blood pressure

Introduction

The hormonal menstrual cycle is a cyclical process in the female reproductive system that is commonly considered the stage of pre-fertilization and pregnancy [1]. The menstrual cycle, an important biological cycle, is characterized by the hypothalamic-pituitary-ovarian axis (HPCA) which regulates it and cyclically secreted steroid and gonadotropic hormones through complex negative and positive feedback pathways [2]. Ovulation at the end of each cycle occurs when a mature follicle releases an egg, resulting in menstruation, the end of the cycle when fertilization is not achieved [3]. Notably, the menstrual cycle is characterized by high individual variability, with cycle lengths typically ranging from 23 to 38 days [3].

The menstrual cycle has three main phases: follicular phase, ovulatory phase, 37 and luteal phase [4]. The follicular phase (pre-ovulatory; proliferative phases) involves raising oestrogen, facilitating ovarian follicle maturity and proliferation [5]. The ovulatory phase is characterized by dropping of oestrogen and increases in

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luteinizing hormone [LH] and follicle-stimulating hormone [FSH], signalling a mature egg being released to be fertilized. The luteal phase, a post-ovulatory secretory phase, is characterized by an increase in progesterone and oestrogen levels released from the corpus luteum [5]. In preparation for implantation (the phase of the uterine stage), the uterine lining thickens, but in absence of fertilization the corpus luteum degenerates, leading to the shedding of the uterine lining that presents itself as menstruation which lasts around 3-5 days [4].

In addition, environmental effects of stress, exercise, diet, and illnesses such as obesity and polycystic ovary syndrome [PCOS] could interfere with the tightly controlled menstrual cycle [6, 7]. Notably, sex hormone receptors in other tissues have been reported, such as in the non-reproductive tissue for oestrogen and progesterone indicating some physiological changes due to hormones that are not solely a reproductive mechanism [8]. Therefore, hormonal variations during the menstrual cycle can cause hemodynamic and psychological manifestations such as mild pain and premenstrual syndrome [PMS] [9]. Women show disturbance, psychological and physiological, in the luteal phase; this is like the symptologic profile of PMS [9]. This indicates that hormonal changes can possibly predispose women to increased emotional sensitivity and stress reactivity [10].

Signals that stress exposure is also contributing to the manifestation of PMS symptoms are that of stress increase in PMS (stress is most reported to be higher in the luteal phase compared to the follicular one) [11, 12]. Environmental and stress-related adverse events have been reported to markedly influences on suffering signs such as pain, water retention, and behavioural changes in the menstrual cycle [11, 13]. Furthermore, there is evidence of heightened physiological stress response to stress during the luteal phase by means of hemodynamic changes, altered adrenocortical activation, and elevated excretion of norepinephrine and adrenaline [14, 15]. Moreover, however, no difference between studies has been reported between the different menstrual phases because various studies reported no variations of adrenocortical response, heart rate or respiratory rate across periods [16].

Given these inconsistencies, the present study is warranted by a need to define better the psychophysiological patterns of stress responses during the various stages of the menstrual cycle.

Understanding how hormonal fluctuations affect stress responses is critical, because stress is deeply embedded in women's health and can worsen conditions such as premenstrual dysphoric disorder [PMDD] and anxiety disorders. By bridging the gap in knowledge, this study sought to contribute with knowledge of information on stress-related conditions during the menstrual cycle. The novelty of this study lies in the blend of psychological and physiological assessments to investigate stress reactivity over time and period phases. While previous studies often considered isolated parameters, this study combines these measures in a cross-sectional fashion, reducing confounders and allowing a phase-specific association. The use of two laboratory-based test sessions over one menstrual cycle additionally adds to the reliability and accuracy of the results.

The research was performed at the All India Institute of Medical Sciences [AIIMS], Gorakhpur, a tertiary care centre in eastern Uttar Pradesh, India, which offers innovative healthcare and research opportunities. This provided an opportunity to recruit a diverse population of women, allowing for generalization of findings into both urban and rural demographics. Both psychological and physiological stress reactivity were assumed as the variables in this study. Physiological stress reactivity was significantly higher during the luteal Phase versus the follicular phase and that these responses shows a positive correlation under stress-inducing conditions. This investigation has the potential to be a bridge to bridging critical gaps in understanding how the hormonal fluctuations, stress, and psychophysiological responses interact to lead to better therapeutic approaches that are unique to women's biological and psychological profiles.

Methodology

This cross-sectional descriptive study was carried out over a two-month period, October to December 2023, at the Department of Physiology, All India Institute of Medical Sciences

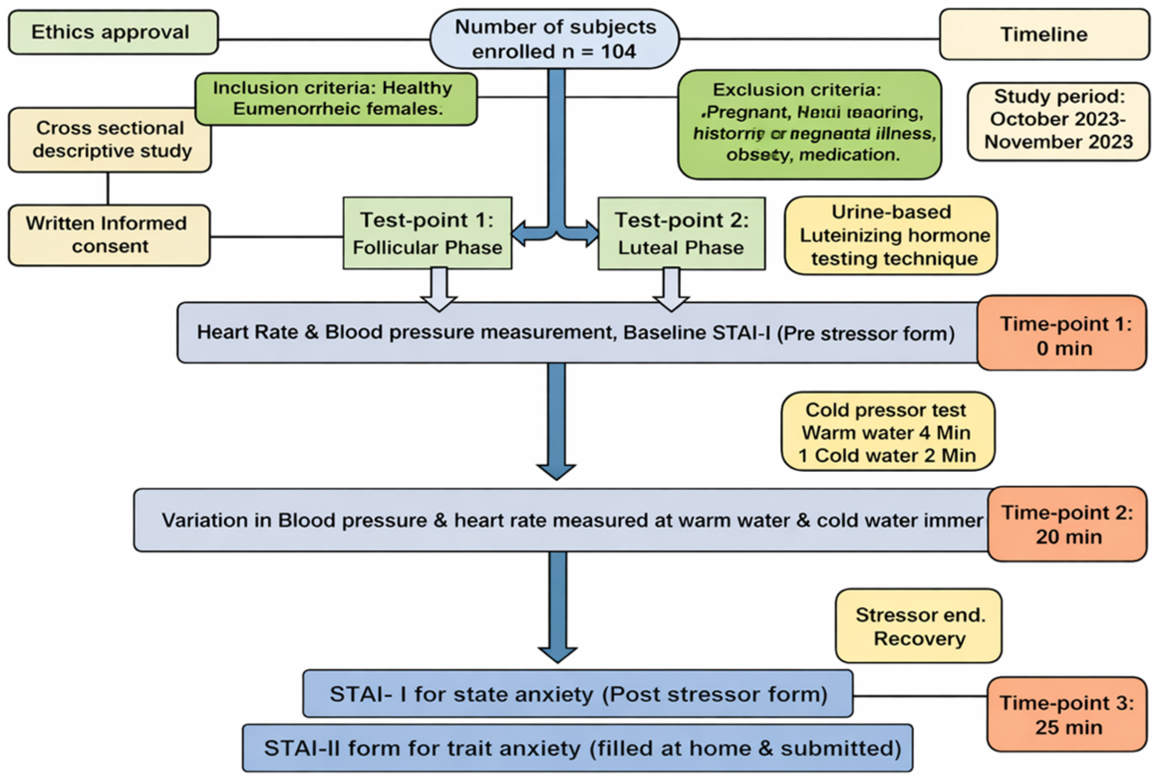

Figure 1. Timeline of data collection for investigations.

[AIIMS], Gorakhpur, a tertiary care centre, Eastern Uttar Pradesh. The research was chosen for study at Indian Council of Medical Research (ICMR), New Delhi, and Short Term Studentship program (STS 2023-07830). The research was done in coordination with the Department of Psychiatry. Study carried out consistent with the Declaration of Helsinki and has commenced upon institutional ethics committee approval committee approval. Ethical approval (IHEC/AIIMS-GKP/BMR/221/2023) was obtained from Human ethical Committee of the institution.

The subjects consisted of eumenorrheic women with normal menstrual cycles. Intended Participants inclusion criteria was aimed to enrol females aged 18 to 30 years with an active menstrual cycle. Exclusion criteria included pre-menarcheal, pregnant, nursing, or amenorrhoeic women, and patients with menstrual cycle disorders, autonomic dysregulation, a history of mental illness, obesity, diabetes, or patients taking hormonal therapies or medications that could impact menstrual cycles. Women with a current or past pregnancy within the last one year were excluded to avoid confounding hormonal and psychophysiological stress responses. These conditions included 104 participants, the sample of whom were recruited, and provided written informed consent before inclusion. A urine-based luteinizing hormone [LH] detection test with a sensitivity range of 10-70 mIU/mL was utilized to detect the menstrual cycle phases. The LH test detects a unique hormonal surge indicative of ovulation, which allowed definitive identification of the follicular and luteal phase for each111participant (**Figure 1**).

Sample size calculation

The sampling size was calculated based on an earlier study conducted by Olson et al. [10], which investigated heart rate variance during menstruation. It was assessed that the final sample size of 104 participants was sufficient for the present study considering an effect size of 4.16 (10.81 standard deviation), power 80%, alpha equal to 0.05.

Data collection

Participants were provided an extensive explanation of study protocol, and familiarity with the instruments, as well as experience with the study techniques was guaranteed for patient's comfort and compliance. Participants were asked to stop the test immediately whenever they felt any pain. A total of menstrual cycles were the following. Each of the participant underwent 2 laboratory sessions in which the follicular and luteal phase were experienced. Demographic and medical history data (age, cycle duration, and medical) were collected before the sessions.

To minimize confounders due to the diurnal nature of cortisol concentrations, all testing sessions were conducted from 10:00 AM to 4:00 PM. A home test with more than 98% accuracy for detecting the LH surge was used to confirm ovulation. Laboratory studies included assessments of baseline systolic and diastolic blood pressure and heart rate before and after the cold pressor test. Blood pressure was assessed by a mercury sphygmomanometer, and heart rate by a 3-lead electrocardiography system.

Assessment of trait and state anxiety

The validated STAI questionnaire was administered to all participants as a measure of trait and state anxiety. This standardized instrument was categorically based on its reliability in assessing subjective stress with minimal disturbance to lab procedures [18]. The STAI includes two 20-item subgroups: STAI-I (which measures state anxiety, which is a momentistic feeling occurring immediately during the cold pressor test), and STAI-II (which measures trait anxiety, which is generalized anxiety over the long term). Responses were rated by participants in a 4-point Likert scale, with the higher the rating, the greater the anxiety [18].

Cold pressor test

The cold pressor test was used, which is a well-known physical stressor to cause measurable hemodynamic and psychological responses [19]. Participants first immersed their hands in warm water [37°C] for 4 min and followed by immersion in cold water (1-3°C) for a maximum of two min. Tests of blood pressure, heart rate during both phases, and changes were noted. The STAI-I questionnaire was administered before and after the stressor, and the STAI-II questionnaire was administered after each testing session [19].

Study parameters and assessment methods

The study assessed both physiological and psychological stress response parameters across the follicular and luteal phases of the menstrual cycle. The physiological parameters included systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR). Baseline SBP, DBP, and HR were recorded in the sitting position after a 10-minute rest period using a calibrated automated sphygmomanometer. Post-stress readings were obtained immediately following the standardized stress-inducing task to evaluate phase-specific cardiovascular reactivity.

The psychological stress response parameters included state anxiety and trait anxiety, measured using the State-Trait Anxiety Inventory (STAI-I and STAI-II). State anxiety was assessed both before and after the stress task to capture acute emotional reactivity, whereas trait anxiety was assessed once in each menstrual phase to reflect the participant's general anxiety disposition. All assessments were conducted under uniform environmental conditions to minimize measurement bias.

Statistical analysis

All statistical analyses were conducted in SPSS version 21.0 and GraphPad Prism 9.0. Quantitative variables were calculated as mean ± standard deviation. The normality of the distribution of data was explored by Kolmogorov-Smirnov test. Paired t-tests or Wilcoxon signed-rank tests were used depending on normality to compare mean differences between the phases. Correlations between study variables were assessed with Spearman's correlation coefficient. A p-value < 0.05 was considered statistically significant.

Statistical analysis of menstrual cycle characteristics

Menstrual cycle-related variables including cycle length, duration of menstruation, regularity of cycles, presence of dysmenorrhea, and premenstrual symptoms were statistically analysed. Descriptive statistics were expressed as mean ± SD for continuous variables and fre-

Table 1. Age and menstrual cycle length of study subjects

Parameter	Mean ± SD	Minimum	Maximum
Age [Years]	20.88 ± 1.75	18	30
Menstrual cycle [days]	30.21 ± 2.4	25	40

Note: Data is expressed in mean ± standard deviation.

quency (%) for categorical variables. Group comparisons between follicular and luteal phases were performed using paired t-tests (or Wilcoxon signed-rank test where appropriate), while categorical variables were analysed using the chi-square test. No statistically significant differences were observed in mean cycle length or duration of menstruation between participants with higher versus lower stress reactivity ($P > 0.05$). However, participants reporting moderate-to-severe premenstrual symptoms demonstrated higher trait anxiety scores in the luteal phase compared to those without symptoms ($P < 0.05$)

Results

General characteristics of study participants

The data recorded from the investigation indicated that the study population's age varied from 18 to 30 years. The mean age of the study population was 20.88 ± 1.75 years (**Table 1**). As per the data recorded, the reported menstrual cycle of the study participants ranged from 25-40 days, with a mean menstrual cycle length of 30.21 ± 2.4 days (**Table 1**).

Assessment of psychological parameters through STAI test

To assess psychological stress reactivity, state trait anxiety inventory [STAI] test was employed. It consisted of 40 questions, divided into two subscales of 20 questions each for STAT-I and STAI-II for the assessment of state anxiety and trait anxiety respectively. The scale contains questions with answers available in 4 different grades. After recording answers, the total raw scores were calculated by adding the scores obtained on each question. Notably, higher the raw score has been reported to indicate higher anxiety and stress. In the current investigation it was identified that state anxiety [STAI-I] scores recorded before the cold pressor test did not vary between follicular and luteal phases. Similarly, no change was noted in state anxiety [STAI-I] scores recorded after the cold pressor test was completed. Notably, when compared with follicular phase, only the trait anxiety score varied significantly [$P = 0.03$], and was elevated in luteal phase among the study participants (**Table 2**).

Additionally, a comparison of state anxiety scores before and after cold pressor test within each menstrual cycle was performed (**Tables 3** and **4**). Notably, it was identified that state anxiety scores did not alter before and after cold pressor test in follicular phase (**Table 3**). However, only in the luteal phase, the state anxiety scores recorded before the test varied significantly when compared to scores recorded after the cold pressor test (**Table 4**).

Assessment of physiological parameters in study subjects

The blood pressure readings were collected both before [basal] and after cold pressor test [pre and post-stressor]. As the cold pressor test involved exposure to hot and cold water, blood pressure readings were collected after both hot and cold water exposure. Notably basal heart rate, basal systolic and basal diastolic pressure were not altered in the study participants between follicular and luteal phases. On comparison with the follicular phase, the diastolic and systolic pressure after hot water exposure was found to be significantly reduced in luteal phase. Moreover, the difference between hot and cold diastolic pressure was also found to be significantly reduced in luteal phases when compared follicular phase (**Table 5**).

Assessment of relationship between study variables

To analyze the association between psychological and physiological parameters, spearman correlation analysis was performed and a correlation matrix representing association of each study variable with the other was generated (**Tables 6** and **7**). It was noted that in follicular phase, age was negatively associated with pre stressor STAI-I scores, while menstrual cycle length was positively associated with pre stressor STAI-I scores in the study subjects.

Table 2. Assessment of psychological parameters by STAI-I test in different menstrual cycle phases among study subjects

Parameter	Follicular Phase			Luteal Phase			*P* value
	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum	
STAI-I pre	37.77 ± 10.97	20	72	38.16 ± 9.4	20	65	0.35
STAI-I post	36.23 ± 9.8	20	67	36.34 ± 9.16	21	67	0.81
Difference in pre and post STAI-I	5.8 ± 6.6	0	37	5.03 ± 4.98	0	26	0.50
STAI-II	41.78 ± 9.82	20	75	43.41 ± 9.98	23	79	0.03*

Note: Data is expressed in mean ± standard deviation. * Indicates P < 0.05.

Table 3. Assessment of psychological parameters by STAI-I test in follicular phase among study subjects

Parameter	Pre-Follicular			Post-Follicular			*P* value
	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum	
STAI-I	37.77 ± 10.97	20	72	36.23 ± 9.8	20	67	0.21

Note: Data is expressed in mean ± standard deviation. * Indicates P < 0.05. STAI: State and trait anxiety inventory.

Table 4. Assessment of psychological parameters by STAI-I test in luteal phase among study subjects

Parameter	Pre-Luteal			Post-Luteal			*P* value
	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum	
STAI-I	38.16 ± 9.4	20	65	36.34 ± 9.16	21	67	0.01*

Note: Data is expressed in mean ± standard deviation. * Indicate P < 0.05.

Moreover, in the follicular phase, a weak positive association was observed between post stressor STAI scores, and diastolic pressure among the study subjects. No other correlation was observed between psychological and physiological parameters in the follicular phase (**Table 6**).

When similar analysis was performed in the luteal phase, post-stressor state anxiety scores were observed to exhibit a weak negative correlation with systolic pressure. No other correlation was observed between psychological and physiological parameters in the luteal phase (**Table 7**).

Discussion

This cross-sectional descriptive study focused on the psychophysiological responses to stress across various phases of the menstrual cycle in healthy eumenorrheic women. A sample of 104 individuals [mean age: 20.88 ± 1.75 y] had cold pressor testing performed, both in the follicular and luteal phases during their menstrual cycles. Stress responses were measured in terms of trait and state anxiety, as well as hemodynamic alterations. The results revealed that basal blood pressure [BP] and heart rate remained unchanged between the follicular and luteal phases, but diastolic BP showed significant alterations in the luteal phase following stress exposure. In addition, trait anxiety was shown to be much more intense in the luteal phase than in the follicular phase: a drop in scores was therefore evident at various sites. Additionally, state anxiety was significantly modulated before and after stress exposure only in the luteal phase, indicating unhealthy psychological reactivity to stress in this phase. Interestingly, physiological and psychological stress reactivity exhibited statistically non-correlations which highlights the intricate and multifactorial nature of these reactions Hormonal fluctuations across the menstrual cycle constantly modulate physiological and psychological processes in females [20]. Stress reactivity, which involves an individual's personal biological and psychological state induced by stress, varies according to the menstrual phase [10, 12]. Grasping these variations is key to further clarifying sex-specific and phase-specific vulnerabilities to stress-related disorders such as anxiety, depression and PMS. While existing research has shed light on the association between menstrual cycle phases and stress reactivity [10, 12, 16], the new study includes psy-

Table 5. Assessment of physiological parameters after cold pressor test in different menstrual cycle phases among study subjects

Parameter	Follicular Phase			Luteal Phase			*P* value
	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum	
Basal heart rate	82.45 ± 11.34	56	126	82.10 ± 11.67	57	115	0.77
Basal systolic BP	110.8 ± 13.99	88	162	108.6 ± 11.03	78	136	0.19
Basal diastolic BP	68.38 ± 12.37	43	128	68.34 ± 12.74	34	113	0.80
Hot systolic BP	109.5 ± 14.53	72	160	105.5 ± 12.48	74	143	0.038*
Hot diastolic BP	71.05 ± 15.17	45	133	67.74 ± 12.43	46	114	0.045*
Cold Systolic BP	109.4 ± 14.70	79	184	110.1 ± 14.29	83	172	0.81
Cold diastolic BP	68.71 ± 12.18	42	124	69.08 ± 13.66	42	143	0.70
Difference between hot and cold systolic BP	9.9 ± 12.04	0	59	9.9 ± 12.59	0	84	0.93
Difference between hot and cold diastolic BP	10.83 ± 11.84	0	74	8.58 ± 12.76	0	78	0.019*

Note: Data is expressed in mean ± standard deviation. * Indicates P < 0.05. BP: Blood pressure.

Table 6. Correlation matrix for the assessment of relationship between study parameters in the Follicular phase

	Age	STAI-I Pre stressor	STAI-I Post stressor	STAI-I Diff.	STAI-II	Basal HR	Basal BP Systolic	Basal BP Diastolic	Hot Systolic	Hot Diastolic	Cold Systolic	Cold Diastolic	Diff. Sys.	Diff. Dias.	Menstrual cycle length
Age		-0.2	-0.1	-0.1	0	0	0.1	0.1	0	0	0	0.2	-0.2	0	-0.1
STAI-I Pre stressor	-0.2*		0.7	0.1	0.6	-0.1	0	-0.1	0	0	-0.1	-0.1	0	0.1	0.2*
STAI-I Post stressor	-0.1	0.7		0	0.7	-0.1	0	-0.1	0.1	0.1	0	-0.1	0	0.3*	0.1
STAI-I Diff. in Pre & Post	-0.1	0.1	0		0.1	0	0.1	0.1	0.1	0.1	0	0	0.1	-0.1	0
STAI-II	0	0.6	0.7	0.1		-0.1	0	-0.2	0.2	0.1	0	-0.1	0.1	0.3	-0.1
Basal HR	0	-0.1	-0.1	0	-0.1		0.2	0.3	0.1	0.2	-0.1	0	0	-0.1	-0.2
Basal BP Systolic	0.1	0	0	0.1	0	0.2		0.6	0.5	0.4	0.6	0.5	0	0.2	0.1
Basal BP Diastolic	0.1	-0.1	-0.1	0.1	-0.2	0.3	0.6		0.4	0.5	0.4	0.6	0	0.1	-0.1
Hot Systolic	0	0	0.1	0.1	0.2	0.1	0.5	0.4		0.6	0.4	0.4	0.2	0.3	0
Hot Diastolic	0	0	0.1	0.1	0.1	0.2	0.4	0.5	0.6		0.2	0.4	0.2	0.2	-0.1
Cold Systolic	0	-0.1	0	0	0	-0.1	0.6	0.4	0.4	0.2		0.6	0.2	0	0
Cold Diastolic	0.2	-0.1	-0.1	0	-0.1	0	0.5	0.6	0.4	0.4	0.6		0	0	-0.1
Diff. Sys.	-0.2	0	0	0.1	0.1	0	0	0	0.2	0.2	0.2	0		0.3	0
Diff. Dias.	0	0.1	0.3	-0.1	0.3	-0.1	0.2	0.1	0.3	0.2	0	0	0.3		0
Menstrual cycle length	-0.1	0.2	0.1	0	-0.1	-0.2	0.1	-0.1	0	-0.1	0	-0.1	0	0	

Note: Data are expressed as mean ± standard deviation. * indicates a statistically significant difference (P < 0.05). BP: blood pressure.

Table 7. Correlation matrix for the assessment of relationship between study parameters in the luteal phase

	Age	STAI-I Pre stressor	STAI-I Post stressor	STAI-I Diff. Pre Post	STAI-II	Basal HR	Basal BP Systolic	Basal BP Diastolic	Hot Systolic	Hot Diastolic	Cold Systolic	Cold Diastolic	Diff. Sys.	Diff. Dias.	Menstrual cycle length
Age		0.02	0	-0.02	-0.07	0	-0.04	0.15	-0.07	0.01	0.01	0.1	0.01	0	-0.07
STAI-I Pre stressor	0.02		0.7	0.15	0.6	0.01	0	0	-0.01	-0.01	-0.18	-0.08	0.08	0.05	-0.07
STAI-I Post stressor	0	0.7		-0.1	0.49	0.01	-0.05	-0.1	-0.12	-0.09	-0.19	-0.13	0.13	0.17	0.09
STAI-I Diff. in Pre & Post	-0.02	0.15	-0.1		0.15	0.14	0.07	-0.01	0.02	0.06	0.17	0.1	0.12	0	-0.2
STAI-II	-0.07	0.6	0.49	0.15		0.01	0.01	0.02	0	0.08	-0.04	0.03	0.12	0.14	-0.08
Basal HR	0	0.01	0.01	0.14	0.01		0.07	0.09	-0.04	0.14	0.07	0.14	0.12	0.01	0.09
Basal BP Systolic	-0.04	0	-0.05	0.07	0.01	0.07		0.57	0.5	0.47	0.51	0.45	0.07	-0.03	-0.05
Basal BP Diastolic	0.15	0	-0.1	-0.01	0.02	0.09	0.57		0.33	0.35	0.4	0.42	-0.07	-0.21	-0.16
Hot Systolic	-0.07	-0.01	-0.12	0.02	0	-0.04	0.5	0.33		0.64	0.46	0.36	-0.01	-0.05	-0.09
Hot Diastolic	0.01	-0.01	-0.09	0.06	0.08	0.14	0.47	0.35	0.64		0.37	0.56	0.04	-0.01	0.07
Cold Systolic	0.01	-0.18	-0.19*	0.17	-0.04	0.07	0.51	0.4	0.46	0.37		0.7	0.41	0.16	-0.08
Cold Diastolic	0.1	-0.08	-0.13	0.1	0.03	0.14	0.45	0.42	0.36	0.56	0.7		0.23	0.16	-0.02
Diff. Sys.	0.01	0.08	0.13	0.12	0.12	0.12	0.07	-0.07	-0.01	0.04	0.41	0.23		0.34	0.05
Diff. Dias.	0	0.05	0.17	0	0.14	0.01	-0.03	-0.21	-0.05	-0.01	0.16	0.16	0.34		0.1
Menstrual cycle length	-0.07	-0.07	0.09	-0.2	-0.08	0.09	-0.05	-0.16	-0.09	0.07	-0.08	-0.02	0.05	0.1	

Note: Data are expressed as mean ± standard deviation. * indicates a statistically significant difference (P < 0.05). BP: blood pressure.

Table 8. Comparative analysis of stress reactivity across menstrual phases

Aspect	Present Study Results	Findings from Previous Studies	Similar Results	Dissimilar Results	Justification	Reference(s)
Baseline Blood Pressure and Heart Rate	No significant differences observed between luteal and follicular phases.	Previous findings are inconsistent; some studies reported no variation across menstrual phases.	Aligned with studies reporting no significant basal BP or HR variation across phases.	Some studies reported variations in basal systolic BP and HR across phases.	Lack of significant change may be due to inter-individual variability and small sample size.	[16, 21]
Post-stress Diastolic Blood Pressure	Significant increase in diastolic BP during luteal phase compared to follicular phase (P < 0.05).	Reduced parasympathetic activity and heightened physiological stress reactivity reported during luteal phase.	Consistent with studies showing increased diastolic BP reactivity in luteal phase during stress exposure.	Contradicts studies reporting no phase-related differences in diastolic BP response.	Alterations may be driven by progesterone-mediated vascular tone and autonomic modulation.	[14-16, 24, 25]
Trait Anxiety (STAI-II)	Significantly higher in luteal phase compared to follicular phase (P = 0.03).	Luteal phase associated with increased psychological distress and anxiety symptoms.	Supports evidence of heightened anxiety and negative affect in luteal phase.	Some studies reported no phase-specific change in trait anxiety.	Increased emotional sensitivity may result from phase-specific hormonal fluctuations.	[16, 30]
State Anxiety (STAI-I, Pre- and Post-stress)	Significant alteration observed only in luteal phase (P = 0.01).	Luteal phase reported to enhance stress sensitivity and emotional reactivity.	Findings match reports of higher stress responsiveness in luteal phase.	Disagrees with studies that did not observe phase-dependent change in state anxiety.	Reflects transient mood reactivity associated with cyclical hormone variations.	[16, 29]
Correlation Between Physiological and Psychological Stress Responses	No significant correlation identified between physiological and psychological parameters.	Literature shows mixed evidence regarding psychophysiological stress link.	Consistent with studies suggesting independent regulatory pathways.	Some studies reported positive correlations between stress parameters.	Absence of correlation may reflect complex neuro-hormonal and behavioural interaction mechanisms.	[26, 32, 33, 35]

Comparison of Stress Reactivity in Menstrual Phases. Unlike other studies, the current one investigated psychophysiological stress responses across different phases of the menstrual cycle with salient results. The results are separated into comparable and dissimilar findings to enhance clarity.

chophysiological indicators to obtain a more thorough assessment of stress responses to hormonal fluctuations. The cold pressor test, a well-known stimulus for inducing stress and for eliciting hemodynamic response, was used to measure physiological stress reactivity. Test: The test activates afferent sensory pathways by exposing you to cold stimuli, inducing sympathetic nervous system reaction, which induces BP upregulation [19].

In contrast to our prediction, basal systolic and diastolic BP followed by heart rate did not differ significantly between follicular and luteal phases. This is in addition to results from Shenoy et al., where there were no significant changes in the basal systolic BP or heart rate during menstrual phases under mental stressors [21]. Yet, diastolic BP showed considerable alterations after stress exposure during the luteal phase in response to the stress, further supporting a maladaptive physiological adaptation to stress. Diastolic BP that is under the control of the parasympathetic nervous system and is indicative of vascular resistance during the resting phases of the heart is attenuated during the luteal phase due to decreased parasympathetic activity [24, 25]. Further studies need to investigate the reciprocal effects of parasympathetic function, hormonal changes and the renin-angiotensin-aldosterone system [RAAS] in stress response during the luteal phase.

Psychological responses of stress were assessed with the State-Trait Anxiety Inventory, where psychological and trait anxiety scores were obtained [27]. Impaired state anxiety, a short-term condition comprising nervousness and tension, was significantly different before and after traumatic stress in the luteal phase but not in the follicular phase [28]. The evidence in favour of a phase-specific maladaptive psychological adjustment to stress in the luteal phase is consistent with earlier evidence for women's greater stress and negative emotions during this phase [29]. In contrast, trait anxiety, defined as a stable tendency to view situations as threatening, was significantly increased in the luteal phase versus in the follicular phase. This supports previous studies showing that negative psychosocial symptoms appear to increase in the luteal phase [30]. The increased trait anxiety in the luteal phase is associated with significant outcomes such as decreased performance and increased susceptibility to stress-induced disorders [31]. Stress-reducing intervention, including mindfulness and yoga, may help eliminate these maladaptive responses, and contribute to an improving overall psychological state [36].

Although psychophysiological responses were rigorously assessed, the present study did not detect a strong association between physiological and psychological stress reactivity during either menstrual phase. This lack of correlation might reflect the complex interaction of genetic, neuroendocrine, and hormonal factors influencing our response to stress [34]. For example, changes in oestradiol activity through the luteal phase may modify hippocampal activity and psychosocial stress reactivity [32]. Furthermore, sympathetic activation under stress and parasympathetic suppression may alter cardiovascular and psychological responses separately, thereby adding an extra layer of complexity to the nexus between them [26, 33]. More interestingly, only a weak positive association was documented where length of menstrual cycle was associated with state anxiety score, indicating bidirectional effects of stress from menstrual cycle type on anxiety and state anxiety scores that need to be confirmed in future study.

Table 8 Comparing psychophysiological stress reactivity from the menstrual phases, similar and different findings were reported compared to previous works. These results are consistent with the existing literature which suggests that maladaptive stress reactivity is related to hormonal variability with menstrual phases. Existing reports like those conducted by Kollipaka et al. also showed that increased stress is associated with a higher prevalence of dysmenorrhea and PMS [35]. Future research should confirm the risk women facing for menstrual irregularities and associated health complications are pre-disposed to maladaptive stress reactivity when they need it. In addition, longitudinal studies that systematically consider the effects of stress-reduction exercises on psychophysiological stress responses across menstrual stages in order to identify new therapeutic techniques to address this, such as yoga or mindfulness, may also provide a useful input [36].

Ultimately, the findings here underscore a considerable change in psychophysiological stress reactivity during the luteal phase, marked as it is by elevated trait anxiety and maladaptive diastolic BP reactivity to stress. These observations highlight the need for phase-specific strategies for examining and addressing stress-related vulnerabilities in women, which may ultimately result in improved quality of life or reduce the burden of stress-related conditions.

There are certain limitations of current study that includes sample size, although it is adequate for initial findings, may limit the generalizability of the results to broader populations. Additionally, the use of luteinizing hormone kits for menstrual phase determination, although accurate, may introduce variability in phase identification. The cold pressor test, as a standardized stressor, may not fully capture real-world stressors experienced by women in diverse socio-cultural settings. Furthermore, the cross-sectional design restricts the ability to analyse changes across multiple cycles or long-term effects. Finally, the study lacks detailed exploration of hormonal assays, which could provide a more precise understanding of hormonal fluctuations and their impact on psychophysiological stress reactivity.

There are some limitations about the current study, with sample size, which may not be able to generalize findings to other populations, despite being sufficiently large to begin with. Also, the luteinizing hormone kits, which are accurate for establishing the period phase, may also potentially lead to differences in the degree to which phases are found in menstruation. The cold pressor test may not represent real stress of women in different socio-cultural environments as a standardized stressor.

Moreover, the cross-sectional design restricts the opportunity to analyse changes between cycles or their impact over time. Finally, the study neglects more detailed hormonal assay work that might give a more complete grasp of hormonal fluctuations and their influence on psychophysiological stress reactivity. Future research should focus on longitudinal studies to monitor stress reactivity over multiple menstrual cycles more thoroughly, particularly in diverse populations. Studies on the effects of psychological interventions such as mindfulness and cognitive behaviour therapy are necessary for different phases of life on particular phases are justified. Moreover, studies investigating the impact of genetic and hormonal influences on stress reactivity can offer insights into phase-specific vulnerabilities. In addition, studies specific to a specific region, in which socio-cultural aspects of socio-cultural factors behind stress responses as well as region-specific stressors can be further enriched by providing insights into the development of interventions, which can help to guide personalized healthcare intervention.

Conclusion

This study provides critical insights into the psychophysiological responses to stress across different menstrual cycle phases. The findings indicate that during the luteal phase, women exhibit maladaptive stress reactivity, characterized by significant alterations in diastolic blood pressure and elevated levels of trait anxiety. These results suggest that genetic predispositions, hormonal fluctuations, and reduced parasympathetic activity during the menstrual cycle may collectively influence women's stress responses. The phase-specific susceptibility to maladaptive stress responses underscores the importance of considering menstrual cycle phases in the evaluation and management of stress-related conditions. These findings have practical implications for developing targeted, phase-specific interventions to improve women's health outcomes. Further research is warranted to elucidate the underlying mechanisms driving these psychophysiological alterations and to explore their broader implications for women's health and well-being.

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Disclosure of conflict of interest

None.

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