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ANXIETY, MENSTRUAL STRESS, AND AUTONOMIC FUNCTION: A STUDY OF HEART RATE AND BLOOD PRESSURE RESPONSES

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ABSTRACT

Background: Anxiety and psychological stress are known to influence autonomic nervous system activity, altering cardiovascular responses through parasympathetic withdrawal and sympathetic activation. Examination-related stress represents a naturalistic model of acute anxiety, while menstrual cycle–related hormonal fluctuations may further modulate autonomic function in young women. Understanding these effects is important for identifying subtle physiological alterations in apparently healthy populations. **Aim:** The present study aimed to evaluate the relationship between anxiety, menstrual stress, and autonomic function using standardized heart rate and blood pressure responses in first-year medical students. **Materials and Methods:** A prospective cohort study was conducted on 120 first-year medical students at S. P. Medical College, Bikaner (2011–2012). Anxiety was assessed using the Spielberger State-Trait Anxiety Inventory (STAI), and female participants were additionally evaluated using a premenstrual stress questionnaire. Autonomic function tests included heart rate variation during deep breathing, the heart rate response to standing (30:15 ratio), the Valsalva maneuver, and blood pressure response to standing. Each participant was assessed at three intervals: pre-examination (baseline), during the first terminal examination, and post-examination (one month later). Female participants were also tested in premenstrual and postmenstrual phases. Statistical analysis was performed using Student's *t* test, with $p < 0.05$ considered significant. **Result:** State anxiety showed a marked impact on autonomic outcomes, with abnormal Valsalva responses increasing from 9.7% to 27.4% in the low-anxiety group and from 13.2% to 34.2% in the high-anxiety group across the study phases. Trait anxiety was associated with more persistent abnormalities, particularly in the Valsalva ratio, rising from 13.6% to 33.3% in high-trait individuals. Menstrual stress analysis revealed non-significant increases in vagally mediated indices such as deep breathing (from 21.85 ± 8.27 bpm to 24.04 ± 8.33 bpm) and standing ratio (from 1.24 ± 0.26 to 1.34 ± 0.25). However, blood pressure response to standing showed a significant premenstrual decline (3.00 ± 3.40 mmHg) compared with postmenstrual values (2.10 ± 2.55 mmHg, $p < 0.001$). **Conclusion:** Examination stress significantly alters autonomic function, with state anxiety driving acute changes and trait anxiety reflecting sustained parasympathetic impairment. Menstrual stress had limited influence on heart-rate indices but significantly affected orthostatic blood pressure, suggesting sympathetic vulnerability in the premenstrual phase. These findings underscore the importance of psychological and hormonal factors in modulating autonomic regulation in young adults.

INTRODUCTION

Anxiety is a common experience in academic settings, but its physiologic footprint is often underappreciated. In health, the autonomic nervous system (ANS) dynamically balances parasympathetic (vagal) and sympathetic influences to maintain cardiovascular stability at rest and during challenge. When anxiety is acute—as during high-stakes examinations—this balance may be perturbed, producing measurable changes in heart rate and blood pressure through baroreflex pathways and cardiovagal modulation. In parallel, cyclical fluctuations in ovarian hormones across the menstrual cycle can also alter autonomic outflow, potentially modifying cardiovascular reflexes and compounding the effects of situational stress in female students. These converging influences motivate a focused investigation of how anxiety (state and trait), menstrual stress, and autonomic function interact in young adults, using standardized bedside autonomic function tests (AFTs) and simple heart- and blood-pressure–based readouts.[1]

Heart rate variability (HRV) offers a noninvasive window onto autonomic control, capturing oscillations in the R-R interval that reflect vagal and sympathetic modulation of the sinoatrial node. Consensus recommendations published in the mid-1990s standardized time- and frequency-domain indices, clarified physiological interpretation, and codified measurement conditions for research and clinical use, emphasizing the sensitivity of vagal-mediated indices to both reflex testing and psychological challenge.[1] These standards underpin contemporary approaches to assessing autonomic balance in relation to mood and stress, and they are complementary to classic AFTs such as the deep-breathing test, the heart-rate response to standing (30:15 ratio), the Valsalva maneuver, and orthostatic blood-pressure measurements—each probing distinct reflex arcs along parasympathetic and sympathetic pathways.

Conceptually, anxiety-related shifts in autonomic output can be framed within the neurovisceral integration model, which links prefrontal–subcortical circuitry for emotion regulation to vagal control of the heart. In this view, effective top-down regulation supports flexible, high-variability cardiac dynamics, whereas anxious states—especially under threat or uncertainty—are associated with reduced vagal tone and altered baroreflex function.[2] This framework helps explain why real-life stressors, such as examinations, may precipitate transient reductions in vagally mediated indices and changes in reflex test performance, even in otherwise healthy individuals. It also offers a rationale for evaluating both state anxiety (context-dependent) and trait anxiety (person-level predisposition), because the latter may confer a more persistent autonomic signature than the former.

Academic examinations have long served as a naturalistic model for studying stress physiology in young adults. Pioneering psychoneuroimmunology studies in medical students documented that the examination period produces measurable biological changes, including altered lymphocyte subsets and dampened immune responses—effects that tracked with perceived stress and loneliness.[3] Subsequent work reinforced that repeated examination exposures can modulate both cellular and humoral immunity, with students reporting lower stress and greater social support showing stronger antibody and T-cell responses.[4] Together, these lines of evidence establish examinations as a robust, ecologically valid stressor capable of shifting multiple physiological systems; by extension, they suggest that cardiac autonomic indices and reflex tests may also show systematic changes across the pre-, during-, and post-examination phases.

Among bedside autonomic tests, the Valsalva maneuver is particularly informative because it engages a well-characterized sequence of hemodynamic phases. During forced expiratory strain, venous return falls, stroke volume declines, and baroreflex-mediated tachycardia emerges; upon release, the rapid overshoot in arterial pressure and reflex bradycardia test the integrity of cardiovagal control.[5] The heart-rate response to standing (quantified by the 30:15 ratio) similarly indexes baroreflex adjustment to a sudden gravitational challenge, while deep-breathing–induced respiratory sinus arrhythmia provides a reproducible probe of efferent vagal function. Together with orthostatic blood pressure, these tests form a compact battery able to detect subtle, stress-related deviations in parasympathetic and sympathetic performance in young cohorts.

Menstrual cycle physiology introduces an additional, potentially interacting layer. Estradiol and progesterone vary across the follicular, peri-ovulatory, and luteal phases, and several studies have shown that baroreflex sensitivity and cardiovagal indices can shift with phase. In controlled experiments, cardiovagal baroreflex responses to pressor stimuli differed between early follicular and mid-luteal phases, suggesting hormone-linked modulation of reflex gain.[6] Likewise, resting HRV has been reported to vary with endogenous hormone levels measured at menses, ovulation, and luteal phases, with lower vagal indices in higher-hormone states in some cohorts.[7] While findings are not uniform across all protocols, the overall pattern supports the hypothesis that menstrual phase can tune autonomic regulation—an effect that may influence how female students respond to situational stressors such as examinations.

MATERIALS AND METHODS

This prospective cohort study evaluated examination-related anxiety, premenstrual stress, and autonomic function—operationalized via heart-rate and blood-pressure responses—in first-year medical students at S.P. Medical College, Bikaner (academic session 2011–2012). From an entering class of 150 students, 100 were selected using a random number table. An additional 20 volunteers were enrolled, yielding a total cohort of n = 120. A predefined female subgroup (n = 20) was assessed for premenstrual symptoms and their relationship to autonomic indices.

Inclusion Criteria: Physically and mentally healthy first-year students in their first academic term.

Exclusion Criteria: Any acute illness (e.g., febrile episode) or current medication that could influence cardiovascular/autonomic function.

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All participants were evaluated at three standardized time points: a pre-examination mid-term baseline, during the first terminal examination (specifically the interval between the essay and practical components), and one month after the first terminal examination (post-examination). To minimize confounding influences, all assessments were performed in the morning in a quiet, temperature-controlled room, and participants were instructed to abstain from caffeine, nicotine, and vigorous exercise for at least 12 hours beforehand.

Methodology

A structured pro forma captured age, sex, nativity, and social, cultural, and lifestyle factors. Written informed consent was obtained from all participants. A structured pro forma captured demographic and background characteristics (name, age, sex, nativity) and social, cultural, and lifestyle factors.

Stress and Anxiety Measures

Stress during the first terminal examination (the students' first major professional assessment) was quantified using two questionnaires:

Spielberger State-Trait Anxiety Inventory (STAI): The inventory comprises two 20-item scales measuring state (A-state) and trait (A-trait) anxiety. Items are rated on a four-point scale, yielding scores from 20 to 80 on each subscale. For analytic comparisons, students were grouped by A-state score during the examination: <40 = low anxiety and >40 = high anxiety.

Premenstrual Stress Questionnaire: Administered to evaluate symptoms relevant to premenstrual stress among female participants.

Autonomic Function Tests (AFTs)

AFTs were performed using a standard electrocardiograph (ECG) and a mercury sphygmomanometer.

Deep Breathing Test (DBT): Participants, seated, performed paced breathing at six breaths per minute. Continuous ECG was recorded for six respiratory cycles with markers for inspiration and expiration. R-R intervals were converted to heart rate, and the Deep Breathing Difference (DBD) was calculated as the mean of the maximum–minimum heart rate difference across six cycles. Interpretation: ≥15 bpm normal; 11–14 bpm borderline; <10 bpm abnormal.

Valsalva Maneuver: Seated participants blew into a mouthpiece connected to a mercury sphygmomanometer to maintain 40 mmHg pressure for 15 s while continuous ECG was recorded, and ECG recording continued for 30 s after release. The Valsalva Ratio (VR) was calculated as maximum R-R interval during the maneuver / minimum R-R interval after the maneuver. Interpretation: ≥1.21 normal; 1.11–1.20 borderline; ≤1.10 abnormal.

Heart Rate Response to Standing (30:15 Ratio / **Postural Tachycardia Index, PTI):**

After resting supine with ECG recording, participants stood unaided and ECG continued for 1 min. The longest R-R interval around the 30th beat and the shortest R-R interval around the 15th beat were identified; PTI = 30th/15th R-R ratio. Interpretation: ≥1.04 normal; 1.01–1.03 borderline; ≤1.00 abnormal.

Blood Pressure Response to Standing (Orthostatic Test): After 5 min supine rest, resting BP was recorded. Participants then stood unsupported; BP was recorded at 30 s and 3 min. The fall in systolic BP from supine to standing was categorized as ≤10 mmHg normal; 11–29 mmHg borderline; ≥30 mmHg abnormal.

Statistical Analysis

Continuous variables were summarized as mean ± SD and compared across time points using paired Student's t-tests (pre vs during; pre vs post; during vs post). Proportions of normal/borderline/abnormal AFT outcomes were compared across phases using McNemar's test when applicable. Two-sided $p < 0.05$ was considered statistically significant. Analyses were performed on the full cohort; exploratory subgroup analyses were conducted for the female premenstrual stress group.

RESULTS

Table 1 shows how autonomic function abnormalities varied between low- and high-anxiety students (based on STAI-State scores) across the three study phases. For the deep breathing test, abnormal responses were more common during the examination period in both groups (14.5% in <40 group and 13.2% in >40 group), though the frequency reduced in the post-exam phase (6.5% and 7.9% respectively). For the standing (30:15) response, abnormalities were most frequent before the examination in both groups (16.1% vs. 15.8%) and declined afterwards, with no abnormal cases in the high-anxiety group after exams. For the Valsalva maneuver, abnormal responses increased progressively from pre- to post-examination in both groups. In the <40 subgroup, abnormal cases rose from 9.7% pre-exam to 27.4% post-exam. In the >40 subgroup, the rise was steeper, from 13.2% pre-exam to 34.2% post-exam.

Table 2 compares autonomic function abnormalities between students grouped by trait anxiety (STAI-Trait <40 vs. >40). For the deep breathing test, abnormalities were slightly higher during examinations (17.6% in <40 group and 12.1% in >40 group), with reduction post-exam, especially in the high-trait anxiety group (4.5%). For the standing (30:15) response, abnormalities were more prominent in the low-trait anxiety group (29.4% at both pre- and post-exam phases) compared to the high-trait group (9.1% pre-exam and none post-exam). For the Valsalva maneuver, the prevalence of abnormal responses was consistently higher in the high-trait group, rising from 13.6% pre-exam to 33.3% post-exam, compared with the lower-trait group (5.9% to 23.5%).

Table 3 evaluates the effect of menstrual cycle phase on heart-rate variation during deep breathing in female students. The mean heart-rate difference

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increased from 21.85 ± 8.27 bpm in the premenstrual phase to 24.04 ± 8.33 bpm in the postmenstrual phase. Although the postmenstrual value was slightly higher, the difference was statistically insignificant ($p = 0.268$).

The standing (30:15) ratio increased from 1.24 ± 0.26 premenstrually to 1.34 ± 0.25 postmenstrually. Although this change suggested improved autonomic adaptability post-menses, the difference did not reach statistical significance ($p = 0.114$).

Valsalva ratio showed little change across menstrual phases, with values of 1.46 ± 0.40 premenstrually and 1.49 ± 0.34 postmenstrually. The difference was minimal and statistically insignificant ($p = 0.630$).

In contrast to heart-rate indices, blood-pressure response to standing was significantly affected by menstrual stress. The mean fall in systolic blood pressure was 3.00 ± 3.40 mmHg premenstrually, compared with 2.10 ± 2.55 mmHg postmenstrually, and the difference was highly significant ($p < 0.001$).

Table 1: Abnormal AFT by Anxiety State group across three intervals

STAI State subgroup	Deep Breathing – Abnormal (No., %)			Standing (30:15) – Abnormal (No., %)			Valsalva – Abnormal (No., %)		
	Pre	During	After	Pre	During	After	Pre	During	After
< 40 (n=62)	7	9	4	10	9	10	6	14	17
	11.3%	14.5%	6.5%	16.1%	14.5%	16.1%	9.7%	22.6%	27.4%
> 40 (n=38)	5	5	3	6	2	0	5	11	13
	13.2%	13.2%	7.9%	15.8%	5.3%	–	13.2%	28.9%	34.2%

Table 2: Abnormal AFT by Anxiety Trait group across three intervals

STAI Trait subgroup	Deep Breathing – Abnormal (No., %)			Standing (30:15) – Abnormal (No., %)			Valsalva – Abnormal (No., %)		
	Pre	During	After	Pre	During	After	Pre	During	After
< 40 (n=34)	4	6	4	10	6	10	2	7	8
	11.8%	17.6%	11.8%	29.4%	17.6%	29.4%	5.9%	20.6%	23.5%
> 40 (n=66)	8	8	3	6	5	0	9	18	22
	12.1%	12.1%	4.5%	9.1%	7.6%	–	13.6%	27.3%	33.3%

Table 3: Menstrual stress: Heart Rate variation during deep breathing

Characteristics	Pre Menstrual	Post Menstrual
Mean	21.85	24.04
SD	8.27	8.33
SE	1.85	1.86
t	1.140	
p	0.268NS	

Table 4: Menstrual stress: Heart Rate response to standing (30:15)

Characteristics	Pre Menstrual	Post Menstrual
Mean	1.24	1.34
SD	0.26	0.25
SE	0.06	0.05
t	1.659	
p	0.114NS	

Table 5: Menstrual stress: Heart Rate response to Valsalva maneuver

Characteristics	Pre Menstrual	Post Menstrual
Mean	1.46	1.49
SD	0.40	0.34
SE	0.09	0.07
t	0.490	
p	0.630	

Table 6: Menstrual stress: Blood Pressure response to standing

Characteristics	Pre Menstrual	Post Menstrual
Mean	3.00	2.10
SD	3.40	2.55
SE	0.76	0.57
t	3.943	
p	<0.001HS	

DISCUSSION

In our cohort, state anxiety tracked with a progressive rise in Valsalva abnormalities: among low-anxiety students (STAI-State <40), abnormal responses increased from 9.7% pre-exam to 27.4% post-exam, and in high-anxiety students (>40) from 13.2% to 34.2%. This pattern aligns with medical-student data showing that a real-life academic stressor shifts autonomic balance toward sympathetic predominance (increased LFnu, reduced baroreflex gain) during stress days compared with control days, consistent with parasympathetic withdrawal under examination load.[8]

For state anxiety vs. deep-breathing and standing (30:15) responses, we saw modest, largely transient abnormalities (deep-breathing during-exam 14.5% in <40 and 13.2% in >40; standing pre-exam 16.1% vs 15.8%, falling thereafter, with 0% abnormal after-exam in >40). Reduced vagal activity during anxious states is well-described in population studies of anxiety disorders, where HRV is significantly lower relative to controls—though part of the association may be medication-related—supporting our observation that vagal-mediated tests are stress-sensitive but may normalize as acute stress abates.[9]

Trait anxiety showed a more persistent parasympathetic decrement: abnormal Valsalva rose from 13.6% pre-exam to 33.3% post-exam in the high-trait group (vs 5.9%→23.5% in low-trait). Experimental evidence indicates high trait anxiety is associated with lower HF power and shorter R-R intervals across both stress and rest, suggesting a sustained vagal deficit; our higher post-exam abnormality percentages mirror that chronic pattern rather than a purely situational effect.[10]

Turning to menstrual phase effects on deep-breathing HR variation, our means increased from 21.85 ± 8.27 bpm (premenstrual) to 24.04 ± 8.33 bpm (postmenstrual) without significance ($p = 0.268$). Studies of healthy women demonstrate lower HF (vagal) power and higher LF/HF in the luteal phase relative to follicular, indicating a modest vagal dip premenstrually; while Yildirir et al. reported significant phase differences in HRV components, our small, nonsignificant rise post-menses is directionally consistent with partial vagal recovery.[11]

For standing (30:15) across menstrual phases, our ratio rose from 1.24 ± 0.26 to 1.34 ± 0.25 ($p = 0.114$), suggesting improved baroreflex/vagal engagement post-menses. Saeki et al. showed that postural autonomic adjustments vary with cycle phase using controlled-breathing HRV, with posture-induced shifts differing between phases; our non-significant improvement is compatible with their conclusion that orthostatic autonomic control has phase dependency, albeit modest in young healthy women.[12]

Our Valsalva ratio changed little across menstrual phases (1.46 ± 0.40 to 1.49 ± 0.34, $p = 0.630$), implying that this vagal-dominant reflex is comparatively stable to menstrual fluctuations in this age band. Classic autonomic testing literature shows heart-rate reflex tests (deep breathing, Valsalva, 30:15) are sensitive to parasympathetic impairment, whereas blood-pressure tests are less frequently abnormal—Ewing et al. reported HR test abnormalities in ~40% vs BP tests <20% in large clinical series—supporting that large menstrual-phase swings are not expected for Valsalva in healthy subjects.[13]

Methodologically, our use of the 30:15 ratio and six-breath deep-breathing follows the standard reflex-test approach; Ryder & Hardisty emphasized how test protocol nuances (e.g., timing of the 30th/15th beat, one vs six breaths) and age-related normal ranges influence sensitivity and interpretation. Your cohort's narrow age range (first-year students) limits age confounding and likely enhances within-subject detection of stress-related change across phases.[14]

Finally, the orthostatic BP response was the only menstrual-phase metric with a significant change in our data (mean systolic fall 3.00 ± 3.40 mmHg premenstrual vs 2.10 ± 2.55 mmHg postmenstrual, $p < 0.001$), pointing to sympathetic vasomotor vulnerability pre-menses. Age-adjusted reflex-test studies in healthy adults show that blood-pressure and heart-rate reflexes vary with physiological context and age; Vita et al. reported that cardiovascular reflex test performance is age-dependent, reinforcing why a young, homogeneous sample (like ours) can reveal subtle physiologic shifts due to menstrual stress without the confounding of age-related declines.[15]

CONCLUSION

In conclusion, this study demonstrates that examination-related anxiety significantly influences autonomic function, with state anxiety producing acute changes and trait anxiety showing more persistent effects. Menstrual stress was associated with subtle, non-significant alterations in heart-rate–based indices but a significant impact on orthostatic blood pressure responses, indicating sympathetic vulnerability in the premenstrual phase. Together, these findings highlight the complex interplay between psychological stress, hormonal fluctuations, and cardiovascular autonomic regulation in young adults.

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