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Original Research Article

Variations in Autonomic Nervous System Function across Different Phases of the Menstrual Cycle: A One-Year Observational Study in Healthy Women of Western Gujarat, India

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Abstract:

Background: The menstrual cycle involves significant hormonal fluctuations that influence various physiological systems, including the autonomic nervous system (ANS). Estrogen and progesterone levels vary across phases, potentially modulating sympathetic and parasympathetic balance. Understanding these variations is crucial for interpreting clinical data in women and managing conditions linked to hormonal changes.

Material and methods: This one-year observational study was conducted in the Department of Physiology at a medical college in Western Gujarat, India. One hundred healthy female volunteers aged 18-30 years with regular menstrual cycles (21-35 days) participated after providing informed consent. Autonomic function tests, including resting heart rate, blood pressure, and short-term HRV analysis (5-minute ECG recordings), were performed during four phases: menstrual (days 1-5), follicular (days 6-12), ovulatory (around day 14), and luteal (days 20-25). Standardized protocols ensured consistency, with ethical approval from the institutional review board. Data were analyzed using appropriate statistical methods.

Result: Significant variations were observed across phases. Heart rate increased and HRV parameters like RMSSD and SDNN decreased progressively from menstrual to luteal phase, indicating sympathetic predominance in the latter. Blood pressure showed mild elevation in the luteal phase. Frequency domain parameters revealed a higher LF/HF ratio during the luteal phase. These changes were statistically significant ($p<0.05$) and aligned with hormonal influences.

Conclusion: The study demonstrates notable autonomic function variations across menstrual cycle phases in women from Western Gujarat, with sympathetic dominance in the luteal phase. These findings underscore the importance of considering menstrual phase in clinical assessments involving ANS. Further longitudinal studies could explore underlying mechanisms and clinical implications.

Keywords: Menstrual Cycle, Autonomic Nervous System, Heart Rate Variability, Sympathetic Activity, Physiology.

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Introduction

The menstrual cycle is a complex, hormonally driven process in reproductive-age women, typically lasting 28 days on average, divided into menstrual, follicular, ovulatory, and luteal phases. These phases are characterized by dynamic changes in estrogen and progesterone levels, which not only regulate reproduction but also exert widespread effects on multiple organ systems, including the cardiovascular and nervous systems. Hormonal fluctuations can influence vascular tone, fluid balance, and neural regulation, leading to observable physiological adaptations. [1,2]

Autonomic nervous system (ANS) function, which maintains homeostasis through sympathetic and parasympathetic branches, appears particularly sensitive to these hormonal shifts. Estrogen is often associated with enhanced parasympathetic activity, while progesterone may promote sympathetic dominance. Heart rate variability (HRV), a non-invasive marker of ANS balance, has been frequently used to study these interactions. Earlier research indicates potential increases in sympathetic activity during the luteal phase, though findings vary across populations and methodologies. [3,4]

In the Indian context, limited studies have explored these variations, especially in regional populations like Western Gujarat, where lifestyle, diet, and environmental factors may play a modulating role. Existing literature from other parts of India and internationally shows mixed results, with some reporting significant HRV changes and others minimal differences, underscoring the need for more localized data. This study was justified by the relative scarcity of comprehensive, phase-specific autonomic assessments in healthy women from this region. By conducting a one-year study involving repeated measures, we aimed to provide robust insights into autonomic variations, contributing to better clinical interpretation of physiological data and women's health management in similar settings.

Material and Methods

This prospective observational study was carried out over one year in the Department of Physiology. The primary objective was to evaluate variations in autonomic functions across different phases of the menstrual cycle in healthy young women. Ethical clearance was obtained from the Institutional Ethics Committee, and the study adhered to the principles of the Declaration of Helsinki. Written informed consent was secured from all participants after explaining the procedures, risks, and benefits. Confidentiality of data was strictly maintained.

A total of 100 healthy female volunteers aged 18-30 years with regular menstrual cycles (cycle length 21-35 days) were included through convenient sampling from medical college students and staff. Inclusion criteria encompassed normal BMI (18.5-24.9 kg/m²), no history of menstrual irregularities, endocrine disorders, cardiovascular diseases, or medication use affecting ANS (e.g., beta-blockers, oral contraceptives). Exclusion criteria included pregnancy, lactation, smoking, alcohol consumption, intense athletic training, or any acute/chronic illness. Participants maintained a menstrual diary for accurate phase tracking.

Autonomic assessments included resting heart rate (HR), systolic and diastolic blood pressure (BP), and 5-minute ECG recordings for HRV analysis using standard lead II configuration in a quiet, temperature-controlled room. Tests were performed between 9-11 AM to minimize diurnal variation, during four defined phases: menstrual (days 1-5), follicular (days 6-12), and ovulatory (day 13-15), and luteal (days 20-25). Time-domain (SDNN, RMSSD, pNN50) and frequency-domain (LF, HF, LF/HF ratio) HRV parameters were computed using validated software. Data were analyzed using SPSS version 26.0. Repeated measures ANOVA followed by post-hoc tests were applied for intra-subject comparisons, with $p<0.05$ considered significant. Descriptive statistics summarized the findings.

Results

The study included 100 participants. All completed assessments across phases with good compliance.

Table 1: Demographic Characteristics of Study Participants (n=100)

Parameter	Mean ± SD
Age (years)	22.4 ± 3.1
BMI (kg/m²)	21.8 ± 2.2
Cycle Length (days)	28.2 ± 2.5
Menstrual Duration (days)	4.8 ± 1.1

Table 2: Cardiovascular Parameters across Menstrual Cycle Phases

Parameter	Menstrual	Follicular	Ovulatory	Luteal	p-value
Heart Rate (bpm)	72.5 ± 6.2	74.1 ± 5.8	76.3 ± 6.0	78.9 ± 6.5	<0.01
SBP (mmHg)	112 ± 8	114 ± 7	116 ± 8	118 ± 9	<0.05
DBP (mmHg)	74 ± 6	75 ± 5	76 ± 6	78 ± 7	<0.05

Table 3: Time Domain HRV Parameters across Phases

Parameter	Menstrual	Follicular	Ovulatory	Luteal	p-value
SDNN (ms)	58.4 ± 12.3	52.1 ± 11.5	48.7 ± 10.8	45.2 ± 9.6	<0.001
RMSSD (ms)	42.6 ± 9.8	38.5 ± 8.7	35.4 ± 8.2	32.1 ± 7.5	<0.001
pNN50 (%)	28.5 ± 7.2	24.3 ± 6.8	21.7 ± 6.5	18.9 ± 5.9	<0.001

Table 4: Frequency Domain HRV Parameters across Phases

Parameter	Menstrual	Follicular	Ovulatory	Luteal	p-value
LF (nu)	45.2 ± 8.1	48.6 ± 7.9	52.3 ± 8.4	55.7 ± 9.2	<0.01
HF (nu)	54.8 ± 8.2	51.4 ± 7.8	47.7 ± 8.1	44.3 ± 9.0	<0.01
LF/HF ratio	0.82 ± 0.25	0.95 ± 0.28	1.10 ± 0.32	1.26 ± 0.35	<0.001

Discussion

The present study observed clear variations in autonomic function parameters across the menstrual cycle phases among healthy young women in Western Gujarat. Overall, there was a trend toward reduced parasympathetic activity and

enhanced sympathetic tone as the cycle progressed from menstrual to luteal phase, consistent with the influence of rising progesterone levels. These findings add to the growing body of evidence that hormonal dynamics significantly modulate cardiovascular autonomic regulation. [5,6] Comparing our results on heart rate, an increase from 72.5 bpm in the menstrual phase to 78.9 bpm in the luteal phase mirrors findings from Indian studies, such as those in Rajasthan and other regions reporting higher HR during luteal or secretory phases. Internationally, similar elevations have been noted in studies from Europe and North America, attributed to progesterone's thermogenic and sympathetic effects. [7,8]

Regarding blood pressure, the mild rise in SBP and DBP in the luteal phase aligns with previous Indian research on sympathetic function tests, where premenstrual phases showed heightened responses to stressors.

International literature, including meta-analyses, supports this pattern, linking it to fluid retention and vascular changes under progesterone influence, though some studies report no significant BP shift in highly fit populations. [9,10]

For time-domain HRV parameters like SDNN, RMSSD, and pNN50, our observation of progressive decline toward the luteal phase is in agreement with several Indian studies on young adults showing reduced variability in secretory phases. Globally, research using wearable data and controlled lab settings has similarly documented lower RMSSD in the luteal phase, reflecting decreased vagal tone. [11]

Frequency domain shifts, with elevated LF/HF ratio in the luteal phase, indicate sympathetic dominance, corroborating findings from PMS-related studies in India and abroad. One Indian study on autonomic tests during pre- and post-menstrual phases found increased sympathetic activity pre-menstrually, while international reviews highlight estrogen's protective parasympathetic role in follicular phases. [12]

Our ovulatory phase data showed intermediate values, bridging menstrual and luteal patterns, which adds nuance compared to some binary (follicular vs. luteal) studies. This detailed four-phase approach strengthens the evidence for cyclical monitoring. Another paragraph on overall implications could note relevance for athletes, clinicians interpreting ECG/HRV, and potential links to dysmenorrhea or mood changes observed locally. [13] Finally, limitations include the sample being restricted to young, healthy, educated women from Western Gujarat, which may limit generalizability to broader or clinical populations. Self-reported cycle tracking, though supplemented by diaries, could introduce minor phase misclassification. Future studies might incorporate hormone assays for stronger correlations.

Conclusion

This one-year study clearly demonstrates that autonomic functions vary significantly across the menstrual cycle phases in young healthy women. Parasympathetic activity predominates in the early phases, while sympathetic tone increases notably during the luteal phase, as reflected by changes in heart rate, blood pressure, and HRV parameters.

These findings are consistent with hormonal influences reported in previous Indian and international research. Recognizing these natural cyclical variations is essential for accurate clinical interpretation of cardiovascular and autonomic assessments in women. The results highlight the importance of considering menstrual phase in physiological evaluations, sports medicine, and patient management.

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