

Research Article

Heart Rate Variability and Autonomic Modulation During the First Year of MBBS Training

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ABSTRACT

Background: Heart rate variability (HRV) is a non-invasive marker of autonomic modulation. Medical training may influence autonomic balance during the first academic year.

Materials and Methods: This observational longitudinal study included 100 first-year MBBS students. Short-term HRV recordings were obtained at three predefined phases of the academic year: within one month of admission (baseline), at six months, and one month prior to end-up examination. Quantitative variables are presented as mean \pm SD. Differences across assessment points were evaluated using repeated-measures analysis of variance (ANOVA). A p-value <0.05 was considered statistically significant.

Results: Parasympathetic indices showed a progressive decline across assessment points,

including pNN50 and high-frequency (HF) power. Measures reflecting autonomic modulation, including low-frequency (LF) power and LF/HF ratio, increased across the academic year.

Conclusion: HRV parameters differed significantly across phases of the first MBBS year, indicating an alteration in autonomic modulation as students progressed through academic training. These findings support the need for student well-being and stress-management initiatives in medical colleges.

Keywords: Heart rate variability; Autonomic nervous system; Medical students; MBBS; Academic stress

INTRODUCTION

Heart rate variability (HRV), defined as the natural beat-to-beat variation in RR intervals,

reflects the continuous interaction between the sympathetic and parasympathetic divisions of the autonomic nervous system (ANS) in regulating cardiac function. Short-term variations in HRV are predominantly mediated by parasympathetic (vagal) activity, whereas long-term fluctuations represent the combined influence of both autonomic branches. Owing to these characteristics, HRV is widely used as a non-invasive indicator of autonomic regulation, physiological adaptability, and early autonomic imbalance.^{1,2}

The sinoatrial node integrates inputs from multiple regulatory systems, including baroreflex mechanisms, thermoregulation, hormonal influences, circadian rhythms, physical activity, and emotional or psychological stimuli, resulting in moment-to-moment variability in heart rate.² Central autonomic integration occurs primarily at the hypothalamic level, which continuously processes internal and external cues to maintain homeostasis. Persistent exposure to stressors such as inadequate sleep, irregular dietary habits, reduced physical activity, limited social support, or sustained emotional strain may disrupt this balance, leading to altered autonomic modulation and reduced HRV. In this context, HRV serves as a useful

physiological marker for understanding how prolonged stress and lifestyle factors influence autonomic function.

Newly admitted medical students are frequently exposed to several of these stressors simultaneously. Entry into medical school is associated with intensive academic demands, transition to new living environments, changes in daily routines, disrupted sleep patterns, and heightened emotional expectations. These factors may render first-year MBBS students particularly susceptible to changes in autonomic regulation. Consequently, HRV assessment has gained attention as an objective method for evaluating the physiological impact of medical training on students' stress responses.

Several studies have examined the relationship between academic stress and HRV, although findings remain variable. Reduced HRV has been associated with altered autonomic regulation during periods of psychological and physiological stress.³ However, Shokr (2015) reported no significant differences in HRV parameters before and after examinations, suggesting the possibility of adaptive responses with repeated exposure to academic stressors.⁴ In contrast, Hammoud et al. (2019) observed the

lowest HRV values before and during examinations, followed by recovery afterward, consistent with transient autonomic changes during acute stress.⁵ Collectively, these studies indicate that academic stress may influence HRV, while also highlighting inconsistencies likely related to differences in study design, timing of measurements, and population characteristics, as many investigations have been cross-sectional in nature.

Beyond academic factors, HRV is influenced by age, sex, circadian rhythms, lifestyle behaviors, and various clinical conditions.⁸⁻¹⁵ Several of these modifying factors frequently undergo changes during the first year of medical training, further emphasizing this period as a critical yet relatively understudied phase. Despite increasing interest in HRV research, longitudinal data examining autonomic changes across the entire first academic year remain limited. Most available studies have focused on isolated examination periods or single time-point assessments, leaving gaps in understanding the cumulative autonomic effects of sustained academic exposure.

The present study was undertaken to address this gap by assessing HRV at multiple time points during the first year of MBBS training.

This approach enables evaluation of changes in autonomic modulation across different phases of the academic year and provides insight into how academic progression and associated lifestyle adjustments may influence autonomic function over time. It was hypothesised that increasing academic demands would be associated with progressive alterations in HRV parameters, reflected by reductions in parasympathetic indices and changes in overall autonomic modulation.

By offering objective physiological data from a longitudinal perspective, this study has potential educational and clinical relevance. The findings may help inform institutional strategies aimed at promoting student well-being, encouraging healthier daily routines, and integrating structured stress-management and wellness initiatives within medical education.

MATERIALS AND METHODS

This observational longitudinal study was conducted in the Department of Physiology, Government Medical College Srinagar, after obtaining approval from the Institutional Ethics Committee. A total of 150 newly admitted first-year MBBS students were screened for participation. Twenty-six

students were excluded based on predefined criteria: 11 were active smokers, 2 were hypertensive, 1 had diabetes mellitus, 4 were taking medications known to influence autonomic function, 8 had hormonal disturbances, and 12 declined to provide informed consent. Among the remaining, 100 participants (50 males and 50 females), aged 18–20 years and apparently healthy at recruitment, were included in the study.

HRV assessments were conducted at three predetermined time points during the first academic year:

- (i) within the first month of admission,
- (ii) at six months, and
- (iii) one month prior to the send-up examination (Pre-University examination).

Inclusion Criteria

- Age 18–20 years
- Newly selected male and female MBBS students
- Female students in their follicular phase of menstrual period

Exclusion Criteria

Participants were excluded if they had any of the following:

- Medical conditions known to affect autonomic function (e.g., anemia, chronic infections, chronic autoimmune disorders)
- Cardiovascular, endocrine, or metabolic illnesses (e.g., cardiac disease, hypertension, diabetes mellitus, thyroid disorders)
- Renal failure
- Pregnancy
- History of significant radiation exposure
- Current intake of medications that influence autonomic regulation
- Malignancy

Data were collected using a semi-structured questionnaire covering socio-demographic characteristics, lifestyle factors, medical history, and drug history, and anthropometric measurements for BMI calculation. Basal heart rate (BHR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were recorded for all participants under standard resting conditions.

Short-term HRV was recorded from resting ECG under standardized conditions using the PowerLab 26T system (ADInstruments, Australia) using standard protocols. Written

informed consent was obtained from all participants prior to data collection.

Data were entered into Microsoft Excel and analyzed using SPSS statistical software (version 23). Quantitative variables were expressed as mean \pm standard deviation (SD). Group-level differences in heart rate variability parameters across the three academic phases were evaluated using repeated-measures analysis of variance (ANOVA). The analysis was intended to identify phase-wise changes at the cohort level rather than to model individual longitudinal trajectories. A p-value less than 0.05 was considered statistically significant.

RESULTS

The demographic details of the eligible participants (Table 1) revealed that while boys and girls were nearly identical in age, the boys exhibited the expected differences in body build. On average, they were taller (1.64 ± 0.15 m) and heavier (65.39 ± 5.19 kg) than the girls (1.49 ± 0.17 m; 49.27 ± 7.26 kg), resulting in a higher mean BMI (23.18 ± 1.05 kg/m² compared with 20.06 ± 1.32 kg/m² in girls). A similar pattern was observed in their blood pressure measurements: boys recorded higher systolic pressures (113.34 ± 17.58 mmHg) than girls (102.71 ± 14.11 mmHg), while diastolic values remained comparable between the groups. These observations reflect the normal physiological differences between male and female students and establish a clear baseline for interpreting subsequent changes in HRV parameters.

Table 1 Demographic characteristics of the participants

PARAMETER	Boys (n=50)	Girls (n=50)
Age in years (Mean \pm SD)	19.12 ± 1.19	18.97 ± 0.91
Height in meters (Mean \pm SD)	1.64 ± 0.15	1.49 ± 0.17
Weight in Kilograms (Mean \pm SD)	65.39 ± 5.19	49.27 ± 7.26
BMI (Mean \pm SD)	23.18 ± 1.05	20.06 ± 1.32

Systolic Blood Pressure mmHg (Mean ± SD)	113.34 ± 17.58	102.71 ± 14.11
Diastolic Blood Pressure mmHg (Mean ± SD)	69.77 ± 6.61	67.92 ± 7.15

Heart rate variability parameters measured at the three time points— Within one month of admission (baseline), six months, and prior to the send-up examination—showed a clear pattern as students progressed through the academic year (Table 2). As academic pressure increased, parasympathetic activity steadily declined. This was evident from the drop in pNN50, which fell from 23.62 ± 10.12 at baseline to 20.12 ± 8.18 at six months, and then to 18.27 ± 8.13 before the examination (p = 0.0431). A similar downward trend was seen in HF power, which decreased from 975 ± 239 ms² to 831 ± 211 ms², and finally to 711 ± 176 ms² (p = 0.0001), indicating reduced vagal influence during periods of academic stress.

In contrast, markers reflecting autonomic modulation increased over time. LF power rose from 1535 ± 630 ms² at baseline to 1781 ± 717 ms², then to 1898 ± 779 ms² (p = 0.0001). Likewise, the LF/HF ratio increased steadily from 0.33 ± 0.12 to 0.36 ± 0.21, and then to 0.41 ± 0.23 (p = 0.0037), reflecting a relative alteration in autonomic balance.

Although heart rate, SDNN, RMSSD, and VLF also changed over the three observations, the variations were mild and did not reach statistical significance. Even so, their overall movement—slightly higher heart rate and SDNN, and modest reductions in RMSSD and VLF—remained in line with the broader pattern of increasing sympathetic drive as students approached examination periods.

Table 2 HRV and its relation to various stages of student life

Parameter (n=100)	Within one month of admission	After Six months	One month prior to send-up Exam	P value
HR (b/min)	72.23 ± 6.69	74.13 ± 5.14	76.47 ± 6.02	0.1931

SDNN (ms)	182.17 ± 46.21	173.21 ± 41.98	168.72 ± 43.36	0.2332
RMSSD (ms)	52.71 ± 17.71	50.63 ± 15.38	48.72 ± 15.27	0.0873
pNN50 (%)	23.62 ± 10.12	20.12 ± 8.18	18.27 ± 8.13	0.0431
VLF (ms²)	4013 ± 2110	3919 ± 1918	3817 ± 1792	0.0991
HF (ms²)	975 ± 239	831 ± 211	711 ± 176	0.0001
LF (ms²)	1535 ± 630	1781 ± 717	1898 ± 779	0.0001
LF/HF ratio	0.33 ± 0.12	0.36 ± 0.21	0.41 ± 0.23	0.0037

DISCUSSION

The present analysis focused on comparing group-level differences in HRV parameters across different academic phases rather than modeling individual longitudinal trajectories. Heart rate variability (HRV) is a widely accepted non-invasive indicator of autonomic nervous system regulation, reflecting the dynamic balance between sympathetic and parasympathetic influences on cardiac function. In the present observational longitudinal study, HRV parameters were assessed at three different phases of the first academic year in MBBS students, providing insight into autonomic modulation as students progressed through medical training.

The findings demonstrate statistically significant differences in key HRV parameters across the three assessment

points. Parasympathetic indices, particularly pNN50 and high-frequency (HF) power, showed a progressive decline from baseline to the pre-examination phase. These parameters are primarily mediated by vagal activity and are known to decrease in states of sustained psychological or physiological strain. The observed reduction in these indices suggests a gradual attenuation of parasympathetic modulation as academic demands increased over time.

Although low-frequency (LF) power and the LF/HF ratio increased across the academic year, these parameters do not represent isolated markers of sympathetic activity. Rather, when interpreted alongside declining parasympathetic indices such as high-frequency (HF) power and pNN50, they reflect an alteration in overall autonomic modulation during periods of sustained

academic demand. This pattern suggests a relative shift in autonomic balance associated with prolonged academic exposure rather than an absolute increase in sympathetic drive. Low-frequency power and the LF/HF ratio were interpreted cautiously, as these parameters do not represent isolated sympathetic activity and should be considered in conjunction with parasympathetic indices such as HF power and pNN50.

Although parameters such as heart rate, SDNN, RMSSD, and VLF did not show statistically significant differences across the assessment points, their overall trends were directionally consistent with the broader pattern of autonomic modulation observed in this study. The absence of statistical significance in these parameters may reflect inter-individual variability and the multifactorial influences on HRV.

The autonomic changes observed in this study are consistent with earlier reports examining HRV in medical students and young adults exposed to academic stress. Previous studies have documented reductions in parasympathetic indices and alterations in autonomic balance during periods of increased academic workload and examinations. The present study adds to existing literature by demonstrating that such

autonomic changes are not confined to isolated examination periods but may evolve progressively across the academic year.

A notable strength of the study is the assessment of HRV at multiple time points within the same cohort, allowing comparison of autonomic parameters across different phases of the academic year. In addition, standardized recording conditions and control of menstrual phase in female participants enhanced the internal consistency of measurements.

Limitations

This study has certain limitations. Raw ECG recordings and the original master datasheet were not retained after completion of statistical analysis, as this was an academic observational study conducted within routine departmental resources; therefore, reanalysis using alternative statistical models was not feasible. Objective assessment of psychological stress, sleep quality, caffeine intake, and physical activity was not performed, and these factors may have influenced HRV measures. The study was conducted at a single institution, which may limit generalizability of the findings.

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