Original Article

DOI: 10.7860/JCDR/2026/76903.22322

Physiology Section

Assessment of Stress in First Year Medical Students by Measuring Heart Rate Variability and its Correlation with Academic Achievement: A Cross-sectional Study

CHIRAG GUPTA[1], NIMARPREET KAUR[2], DEEPTI DWIVEDI[3], KESHAV VERMA[4], SEHAN[5]

ABSTRACT

Introduction: Academic stress can inhibit and suppress learning, a phenomenon referred to as "unfavorable stress," which is associated with diminished academic performance. It is a proven fact that medical students experience this stress from the moment they enter the profession, and it continues throughout their lives. Therefore, the association between stress and cardiac autonomic functions has been studied. Exposure to various stressors stimulates multiple stress-controlling mechanisms in the body. The primary focus of the present study was to measure stress and its effects on the cardiovascular system, as well as its subsequent impact on academic performance.

Aim: To measure stress in medical students using Heart Rate Variability (HRV) and Perceived Stress Scale (PSS) scores, and to relate these measurements to their academic achievements.

Materials and Methods: The present cross-sectional observational study was conducted on 60 healthy medical students at Faculty of Medicine and Health Sciences (FMHS) SGT Medical College, Gurugram, Haryana, India, after obtaining approval from the Institutional Ethics Committee. The study lasted for two months, from June 2022 to July 2022. All enrolled students who provided consent and were studying during the study period were selected through a random allocation technique. One week before the sessional examinations, PSS scores, 15 minutes of HRV data, and scores from Multiple-Choice Questions (MCQs) were obtained. Statistical analysis was performed using Analysis of Variance (ANOVA), which showed significant results with $p<0.005$. Out of 150 students, a total of 60 were included in the study. Demographic parameters were not considered, and ANOVA and t-tests were used with a confidence interval of 95%. A p-value less than 0.05 was considered significant.

Results: A total of 44 (73.33%) students reported moderate stress one week before the first internal examination, while only 24 (40%) students reported moderate stress one week before the second internal examination. This highlights that coping strategies help individuals tackle stressful situations.

Conclusion: Stress can be beneficial to some extent for the academic achievement of students, but not always. Additionally, the present study provides insights into understanding the stress levels of students from the onset, which can assist them in managing schoolwork and academic achievements.

Keywords: Autonomic function, Coping mechanism, Increased cortisol level, Perceived stress

INTRODUCTION

The first year of medical college presents a massive challenge as students transition into a professional life that alters their lifestyle. They must learn to balance academic, professional, and personal responsibilities. Stress is a continuous phenomenon that occurs from childhood into adult life. Although stress has a psychological origin, it affects several physiological processes in the body, such as an increase in cortisol levels and its impact on HRV [1,2].

Academic stress is a common challenge faced by medical students. Various reasons or stressors contribute to this stress, including lecture overload, heavy workloads, difficulties in understanding content, financial problems, and relationships with lecturers and fellow students, among other social, environmental, and cultural factors [3]. Academic stress can inhibit and suppress learning, which is classified as "unfavorable stress" and is associated with reduced academic performance [4]. Academic stress is a major source of stress among adolescents and may lead to low self-esteem [5]. Many psychological problems, such as depression and suicide, result from low self-esteem. While many studies have established that medical students experience stress during their academic years, only a few have explored the relationship between stress and HRV [6-8].

Primarily, the stress levels were assessed using various questionnaires, and responses were measured through scores. The PSS is a widely used psychological instrument for measuring stress perception. The PSS-10 scale specifically measures stress levels in individuals' lives. Four items are scored in reverse (items 4, 5, 7, and 8) as follows: (0=4, 1=3, 2=2, 3=1, 4=0), and the total score is then summed across all scale items [9].

The HRV analysis is a reliable, reproducible, and non-invasive method for quantitatively evaluating sympathetic and parasympathetic activity by continuously recording the Electrocardiogram (ECG) for 15 minutes. In the present study, the authors utilised two tools (qualitative and quantitative) to assess stress levels: the PSS and HRV. Additionally, HRV correlates with mental and psychological states influencing stress due to various academic examinations faced by students [10,11].

The aim of the present study was to measure the level of stress and correlate its effects on the academic performance of medical students. The objectives of the study were to measure stress levels in medical students by:

- Measuring HRV.
- Assessing PSS scores.
- Correlating these findings with academic scores.

MATERIALS AND METHODS

The present cross-sectional observational study was conducted in the Department of Physiology at FMHS, SGT University, Gurugram, Haryana, India, involving 60 healthy medical students (ages 18-21) after approval from the Institutional Ethics Committee. The study duration was from June 2022 to July 2022, following approval from the Institutional Ethics Committee (vide no IEC/FMHS/17/06/22-31).

Inclusion criteria:

- All enrolled students who provided consent.
- Students enrolled during the study period, selected randomly using a chit system.

Exclusion criteria:

- Students with any history of neurological disorders.
- Any pre-existing stress or chronic conditions.
- Use of medication affecting emotional status.
- Any cardiovascular abnormalities.

Study Procedure

The following parameters were studied 15 days before the sessional examinations:

- Perceived Stress Scale (PSS).
- Pulse rate and blood pressure.
- Heart Rate (HR) measured through 15 minutes of HRV.
- Test scores from multiple-choice questions (MCQs).

The Perceived Stress Survey was used to assess sources of stressors, with respondents providing a "Yes" or "No" answer to each item experienced during the current college year. The PSS is a psychological instrument widely used for measuring stress perception, with questions addressing feelings and thoughts over the past month. The PSS-10 scale quantifies stress levels in individuals' lives. Four items are scored in reverse (items 4, 5, 7, and 8) as follows: (0=4, 1=3, 2=2, 3=1, 4=0), and the total score is then summed across all scale items [9].

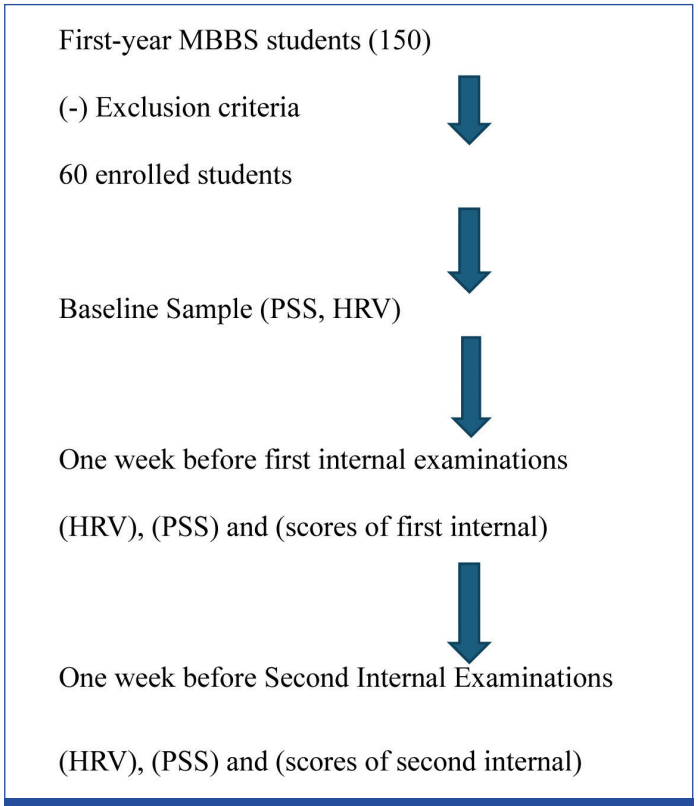
HRV was assessed using Physio-Pac HRV analytic equipment. HRV was continuously recorded for 15 minutes via ECG to quantify sympathetic and parasympathetic tone. The R wave was detected from the QRS complex, with the time interval between two successive heartbeats known as the RR interval. The RR interval on the ECG provides information about the subject's HR. Subjects were asked to lie in a supine position and relax for one minute before limb leads were applied. They were instructed to close their eyes, avoid sleep, and refrain from moving their arms and legs while using the Physio-Pac HRV analytic equipment. The HRV record was obtained [10].

The MCQs were based on core physiology, comprising a total of 30 questions. The set of questions differed for the first and second internal examinations, reflecting the varied syllabi for each. However, the MCQs were categorised by difficulty level: easy, moderate, and difficult.

The criteria for enrollment involved systematic random sampling from a class of 150 students. Out of this class, 60 students were enrolled. The method of selection included the 1st, 3rd, 5th, and 7th students from every group of 10 based on their registration numbers. If a selected student met the exclusion criteria, he/she was replaced by the next student on the list.

After applying the exclusion criteria, 60 students were enrolled. Baseline samples were collected, including HRV measurements and completion of the PSS. One week before the internal examination, HRV, PSS, and scores from the first internal examination were recorded. A second sampling was conducted prior to the second internal examination [Table/Fig-1].

Test score assessment: Test scores were evaluated using a set of 30 MCQs, administered over 30 minutes. This set included five easy questions, 15 medium questions, and 10 difficult questions. No prior information about the MCQ questions was provided before the test. The scores from the first and second internal examinations were taken into account for assessment and evaluation. The MCQ scores were analysed and interpreted alongside HRV data. Continuous data were summarised as mean±Standard Deviation (SD), while discrete data were presented as numbers and percentages.



[Table/Fig-1]: Flow of the study.

STATISTICAL ANALYSIS

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) software, and data were expressed as mean±SD. ANOVA was utilised to compare the means across the three time points. Pearson correlation coefficients were calculated to examine the correlation between the summative scores at the end of the first and second internal examinations. A p-value of <0.05 was considered significant.

RESULTS

Total 60 male first year medical students were included in the study. [Table/Fig-2] shows the comparison of perceived stress scores at different time intervals. A total of 44 students (73.3%) demonstrated moderate levels of stress, while 14 students (23.3%) exhibited high levels of stress one week before the first internal exam. In contrast, 36 students (60%) showed low levels of stress one week before the second internal exam, and 24 students (40%) displayed moderate levels of stress.

[Table/Fig-3] shows the comparison of the LF/HF ratio and perceived stress score at different intervals, indicating a statistically significant difference at both time intervals. The baseline values of the LF/HF ratio were 7.62±2.78, while the values before the first and second internal exams showed a rising trend, indicating a shift in autonomic balance towards sympathetic dominance.

Students were graded according to their academic performance, categorised into three groups based on the marks obtained: poor performers, average performers, and good performers, as shown in [Table/Fig-4]. Poor performers scored less than 50%, moderate performers scored between 50% and 80%, and good performers scored over 80%. [Table/Fig-5-7] shows the correlation between the LF/HF ratio and the first and second internal exams.

PSS score	Status	1 week before 1st internal exam		1 week before 2nd internal exam		p-value
		N (%)	Mean±SD	N (%)	Mean±SD	
0-13	Low stress	2 (3.3%)	12±0.00	36 (60.0%)	10.08±2.06	<0.0001**
14-26	Moderate stress	44 (73.3%)	19.43±4.04	24 (40.0%)	17.21±3.12	0.014*
27-40	High Stress	14 (23.3%)	29.71±2.58	0 (0.0%)	-	-

[Table/Fig-2]: Comparison of perceived stress score at a different time interval.

Parameters	Baseline Mean±SD	1 week before 1st internal exam Mean±SD	1 week before 2nd internal exam, Mean±SD	p-value	F value
LF/HF	7.62±2.78	9.76±4.63	9.83±3.55	<0.0001**	15.83
Perceived stress score	10.40±3.35	21.58±5.97	12.93±4.33	<0.0001**	341.34

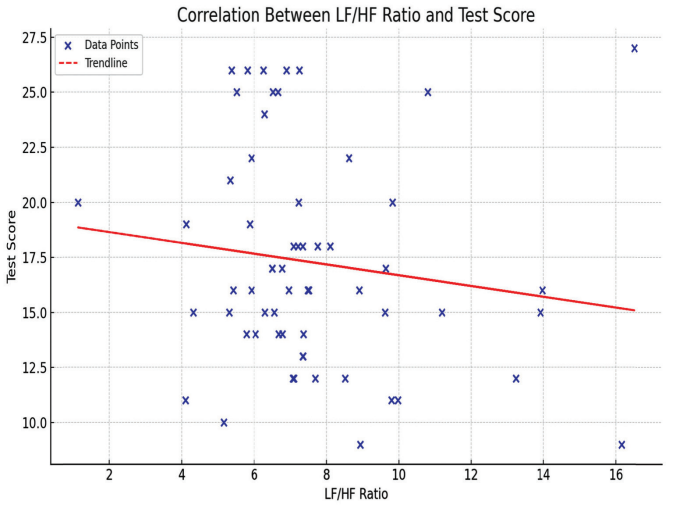
[Table/Fig-3]: Comparison of LF/HF and perceived stress score at different intervals.
*LF: Low frequency; *HF: High frequency

Difficulty level of question	Internal exam	Poor performer		Moderate performer		Good performer		F-Value
		Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value	
Easy	1st term	1.51±0.51	0.06	3.52±0.50	<0.0001**	4.25±0.45	<0.0001**	285.34
	2nd term	1.68±0.5		3.86±0.3		4.69±0.45		511.79
Moderate	1st term	6.83±3.66	<0.0001**	9.40±1.29	0.001*	13.70±0.78	0.05	63.32
	2nd term	4.37±2.08		9.32±0.57		13.62±0.73		353.22
Difficult	1st term	3.30±1.43	0.21	6.33±0.49	0.37	8.32±0.51	0.38	183.26
	2nd term	2.96±1.59		6.42±0.50		8.40±0.51		209.98

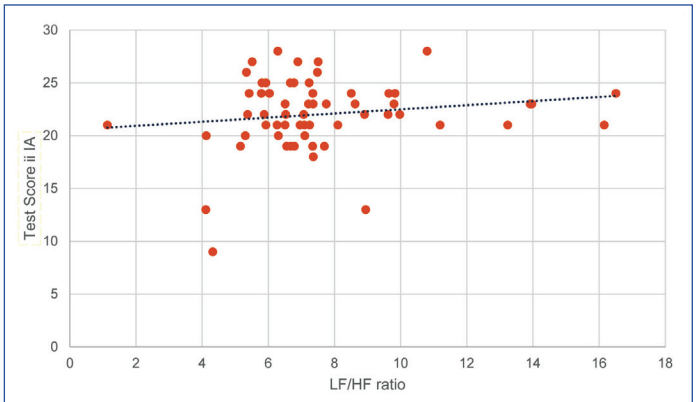
[Table/Fig-4]: Distribution of academic performance of students in internals examinations.

Parameters	Pearson Correlation	p-value
First internal assessment and LF/HF ratio	-0.13	0.32
Second internal assessment and LF/HF ratio	0.159	0.22

[Table/Fig-5]: Correlation between LF/HF ratio with first internal exams and second internal exams.
*LF: Low frequency; *HF: High frequency



[Table/Fig-6]: Correlation between LF/HF ratio and 1st test score.
Test scores plotted on Y axis is out of 30 as it is the total score of all the three types of questions



[Table/Fig-7]: Correlation between LF/HF ratio and 2nd test score.
Test scores plotted on Y axis is out of 30 as it is the total score of all the three types of questions

DISCUSSION

Heart Rate Variability (HRV) is a biological marker of stress in humans. In the present study, the authors aimed to investigate the association between stress and HRV parameters concerning academic performance among first-year medical students. The observations depict that as soon as students enter the medical profession, various stressors impact their physical and mental well-being, with academic pressures acting as the major stressor.

According to the present study, 73% of students experienced moderate stress before the first internal exams, which reduced to 40% before the second internal, highlighting that coping strategies help individuals tackle stressful situations. As medical students come from different cultures and possess varying degrees of coping skills, their responses to stress differ. High levels of stress can cause physical and mental health issues, which, in turn, affect their academic performance and personal and professional development [12]. The present study results align with findings from Gupta S et al., and Abraham RR et al., [13,14].

The present study measured stress levels through HRV and qualitatively via the PSS scores. The results show that stress, measured by HRV and PSS, was found to be statistically significant when analysed at different time intervals during the students' schedules, as evidenced in [Table/Fig-2]. Stress affects autonomic balance, shifting toward a sympathetic predominant state, which can have long-term implications for cardiovascular health.

The HRV parameters reflected by the LF/HF ratio measure the sympatho-vagal balance. In summary, there is a strong relationship between the mean RR interval and various time-domain indices of HRV. HRV was higher during longer mean RR intervals than during shorter ones. Frequency domain analysis of HRV is primarily influenced by the mean HR. The subject's HR was found to be directly associated with LF and indirectly related to HF. Consequently, the LF/HF ratio fluctuated based on HR, with lower values observed at slower HRs and larger values at faster HRs. Thus, HR is a critical factor influencing the LF/HF ratio, independent of changes in cardiac autonomic activity [15].

Although academic pressure is a significant stress factor and academic achievement is an important indicator of educational outcomes, our study results show a negative correlation: students with high stress experienced poor performance before the first internals. However, as the students settled into their professional careers, coping with stress improved, leading to better performance.

Good performers consistently improved or maintained high scores across all types of questions, while moderate performers showed small gains or stability. Poor performers, on the other hand, either regressed or stagnated, particularly with moderate and difficult items. The F-values increased from the first to the second term, indicating increasing divergence in group performance over time. Easy questions showed the most improvement across all groups, while moderate questions revealed the sharpest declines among weaker students. Difficult questions were most effective in distinguishing ability levels, as reflected in [Table/Fig-4].

While appropriate stress can be beneficial in stimulating learning and memory in students, previous studies have yielded mixed results regarding the relationship between stress and academic achievement. Our findings are consistent with a study conducted on dental students by Crego A et al., [16]. When students are not stressed, their attention tends to wander, but as stress levels increase, their focus improves, enhancing academic performance. However, sustained stress negatively affects academic achievement.

In the present study, it was observed that upon entering professional life and experiencing a significant shift in curriculum from 12th grade to professional college, many students faced substantial stress, which impacted their academic performance. This acute stress resulted from various factors, including transitioning to hostel life, making new friends, cultural changes, and adapting to new academic demands.

As students adjusted to college life and established new friendships and routines, their body's homoeostatic mechanisms began to function normally. This adaptation led to improved academic performance. Conversely, when individuals struggle to cope with stressors or endure repeated stress, the autonomic nervous system can become imbalanced, resulting in emotional anxiety, depression, and sympatho-vagal imbalance. This imbalance can cause mental or physical dysfunctions that disrupt homoeostasis, emphasisng the need to recognise and manage stress for overall well-being.

Limitation(s)

The sample size was limited due to time constraints related to the Indian Council of Medical Research - Short Term Studentship (ICMR -STS) grant. The authors plan to conduct a longitudinal study to further investigate the impact.

CONCLUSION(S)

The authors concluded that they measured the level of stress and correlated its effects on the academic performance of medical students both qualitatively and quantitatively. In summary, the study found that while stress can be beneficial to some extent for academic achievement, it is not always advantageous. Additionally, the present study provides insights into understanding students' stress levels during the initial phase of their education, which can assist in managing academic performance.

Acknowledgements

The present study was funded by the ICMR (Ref ID-2022-06848) as an STS project. Chirag was the main author, guided by Dr. Nimarpreet. Keshav and Sehan assisted in data collection, while Dr. Deepti Dwivedi helped with statistical analysis. We thank all contributors and the funding agency for their full support.

REFERENCES

[1] Taelman J, Vandeput S, Spaepen A, Van Huffel S. Influence of mental stress on heart rate and heart rate variability. IFMBE. 2009. IFMBE Proceedings. 2008;22:1366-69.
[2] Pulopulos MM, Vanderhasselt MA, Raedt RD. Association between changes in heart rate variability during the anticipation of a stressful situation and the stress-induced cortisol response. Psychoneuroendocrinology. 2018;94:63-71.
[3] Bergmann C, Muth T, Loerbroks A. Medical students' perceptions of stress due to academic studies and its interrelationships with other domains of life: A qualitative study. Med Educ Online. 2019;24(1):1603526.
[4] Linn BS, Zeppa R. Stress in junior medical students: Relationship to personality and performance. J Med Educ. 1984;59(1):07-12.
[5] Nikitha S, Jose TT, Valsaraj BP. A Correlational study on academic stress and self-esteem among higher secondary students in selected schools of Udupi district.NUJHS. 2014;4(1):106-10.
[6] Ishak W, Nikravesh R, Lederer S, Perry R, Ogunyemi D, Bernstein C. Burnout in medical students: a systematic review. Clin Teach. 2013;10(4):242-45.
[7] Sohail N. Stress and academic performance among medical students. J Coll Physicians Surg Pak. 2013;23(1):67-71.
[8] Lal K. Academic Stress among Adolescent in Relation to Intelligence and Demographic Factors. 2014:5(1):123-29.
[9] Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. J Health Soc Behav. 1983;24(4):385-96.
[10] Cipryan L, Litschmannova M. Intra-day and inter-day reliability of heart rate variability measurement. J Sports Sci. 2013;31(2):150-58.
[11] Park JE, Lee JY, Kang SH, Choi JH, Kim TY, So HS, et al. Heart rate variability of chronic posttraumatic stress disorder in the Korean veterans. Psychiatry Res. 2017;255:72-77.
[12] Sarkar D, Saha J. Assessment of stress among first-year medical students of Chhattisgarh. IOSR J Dent Med Sci. 2015;14:37-40.
[13] Gupta S, Choudhury S, Das M, Mondol A, Pradhan R. Factors causing stress among students of a medical college in Kolkata, India. Educ Health (Abingdon) 2015;28:92-95.
[14] Abraham RR, Zulkifli EM, Fan ES, Xin GN, Lim JT. A report on stress among first-year students in an Indian medical school. South East Asian J Med Educ. 2009;3:78-81.
[15] Billman GE. The LF/HF ratio does not accurately measure cardiac sympatho-vagal balance. Front Physiol. 2013;4:26.
[16] Crego A, Carrillo-Diaz M, Armfield JM, Romero M. Stress and academic performance in dental students: The role of coping strategies and examination-related self-efficacy. J Dent Educ. 2016;80(2):165-72.

PARTICULARS OF CONTRIBUTORS:
1. Interns, Faculty of Medicine and Health Sciences, SGT University, Gurugram, Haryana, India.
2. Professor, Department of Physiology, Faculty of Medicine and Health Sciences, SGT University, Gurugram, Haryana, India.
3. Associate Professor, Department of Physiology, Faculty of Medicine and Health Sciences, SGT University, Gurugram, Haryana, India.
4. Interns, Faculty of Medicine and Health Sciences, SGT University, Gurugram, Haryana, India.
5. Interns, Faculty of Medicine and Health Sciences, SGT University, Gurugram, Haryana, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Nimarpreet Kaur,
Faculty of Medicine and Health Sciences, SGT University, Gurugram,
Haryana, India.
Email: dr.nimarpreet@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Dec 01, 2024
- Manual Googling: Aug 02, 2025
- iThenticate Software: Aug 05, 2025 (10%)

ETYMOLOGY: Author Origin

EMENDATIONS: 10

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Nov 30, 2024**
Date of Peer Review: **Jan 13, 2025**
Date of Acceptance: **Aug 07, 2025**
Date of Publishing: **Jan 01, 2026**