ORIGINAL ARTICLE

Effect of Sleep Quality on Heart Rate Variability in Medical Students: A Cross-sectional Study

Prachi Dawer[1], Kaushal Kumar Alam[2*], Ghanshyam Mishra[3], Manish Gupta[4]

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Abstract

Background: Globally, medical students had demonstrated poor sleep quality. Poor sleep can negatively affect cardiovascular functions. The autonomic nervous system (ANS) regulates cardiovascular function during the sleep-wake cycle and can be monitored by heart rate variability (HRV). The primary objective was to determine any association between sleep quality and HRV parameters in medical students.

Materials and methods: A cross-sectional study was conducted at a single institution in North India. The Pittsburgh Sleep Quality Index (PSQI) was used to assess sleep quality. HRV was recorded using Power Lab AD Instrument (Australia). The correlation between HRV variables and sleep parameters was estimated using Pearson's correlation coefficient and Spearman correlation based on the normality test.

Results: A total of 84 medical students (54 males and 30 females) participated in the study. The mean total PSQI score was 6.44 (SD = 2.62). There was a statistically significant negative correlation between PSQI global score and HRV indices high frequency (HF), root mean square successive difference (RMSSD), and the proportion of differences in consecutive RR intervals that are longer than 50 ms in % (pRR50). A statistically significant positive correlation between PSQI global score and low frequency (LF), and LF/HF ratio was found.

Conclusion: The present study found that parasympathetic-related indices (RMSSD, pRR50, and HF) were inversely correlated to poor sleep quality and directly related to sympathetic indices (LF and LF/HF). This suggests that the poorer the sleep quality, the less is the parasympathetic activity and the more is the sympathetic activity.

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Introduction

Sleep is a biological circadian phenomenon that is related to physical and mental functions.[1] The medical curriculum is one of the stressful courses worldwide and presents increased academic demands and stress levels. Various studies worldwide have found that medical students have poor sleep quality.[2]

Various evidence shows that poor sleep negatively affects not only cognitive functions but also cardiovascular functions.[3] The effect of alteration in sleep on the cardiovascular system may be partially mediated through the autonomic nervous system (ANS).[4] ANS plays a vital role in sleep and can be monitored by heart rate variability (HRV).[5] HRV refers to the variation in time intervals between consecutive heartbeats, which is determined by the duration of interbeat periods.[6] The Pittsburgh Sleep Quality Index (PSQI) is a gold standard questionnaire for evaluating sleep quality and is validated across various populations.[2]

In the literature search, we found studies on sleep quality and HRV conducted in other countries, but not much has been done in India, especially focusing on medical students.[7,8] Therefore, we aimed to study the effect of sleep quality on various parameters of HRV in medical students. The hypothesis in this study was that medical students would indicate low sleep quality and that it would correlate with HRV parameters. The primary objective was to determine any association between sleep quality and HRV parameters in medical students.

Materials and Methods

This descriptive cross-sectional study was conducted in the Autonomic Function Lab of the Department of Physiology, University College of Medical Sciences, Delhi, India, from September 2023 to November 2023. Approval from the Institutional Ethics Committee (IECHR-2023-60-7-R1) was obtained before the initiation of the study.

Study Population

First- and second-year students pursuing the undergraduate medical course were considered because final-year students may possess improved coping mechanisms for their studies.[2]

Inclusion Criteria

- Age between 18 and 25 years.
- Normal body mass index (BMI) (18.5–24.9 kg/m^2).

Exclusion Criteria

- On medication known to affect ANS (antihypertensive, antiepileptic, anxiolytics, and beta-blockers).
- History of diabetes mellitus, hypertension, mental illness, hormonal disorders, and other disorders known to affect ANS.
- Students who are currently smoking, consuming alcohol, or on regular physical activity.

Sample Size

Based on the primary objective, a sample of 84 subjects was required. The sample size was estimated using G*Power 3.1 software, assuming a low correlation of 0.3, a level of significance of 5%, a two-tailed alternative hypothesis, and a power of 0.8.[9] The sampling method used was nonrandom convenience sampling.

Study Tools

The questionnaire consists of two sections: the first section contains demographics such as age, gender, academic year, and residence, and the second section contains the Pittsburgh Sleep Quality Index (PSQI).

Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index questionnaire assesses sleep quality over a 1-month time interval. It consists of 19 items and evaluates seven key areas: sleep latency, subjective sleep quality, habitual sleep efficiency, sleep duration, sleep disturbances, use of sleeping medication, and daytime dysfunction experienced in the past month. Each item is scored on a scale of 1–3, with

[1]Final year MBBS Student; [2]Associate Professor, Department of Physiology, University College of Medical Sciences and GTB Hospital, Delhi; [3]Assistant Professor, Department of Physiology, Autonomous State Medical College, Auraiya, Uttar Pradesh; [4]Professor, Department of Physiology, University College of Medical Sciences and Guru Teg Bahadur Hospital, Delhi, India; *Corresponding Author

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3 indicating the most severe sleep issues. The total score on the PSQI can range from 0 to 21. A combined score of all seven components is known as the "global score of PSQI." A global PSQI score of 5 or higher suggests poor sleep quality, while a lower score indicates better sleep quality. The PSQI has demonstrated internal consistency and reliability, with a Cronbach's alpha coefficient of 0.83 for its seven components.[10] In the current study, the Cronbach's alpha was found to be 0.64. This indicates that the questionnaire is a reliable tool for assessing sleep quality.

Recording of Heart Rate Variability

Heart rate variability was recorded in the Autonomic Function Lab of the department using Power Lab AD Instrument (Australia) equipment. Participants were advised to refrain from caffeine for 24 hours before the recording. Recordings were done with subjects in loose clothing and after voiding urine.[11]

For recording HRV, the standard limb lead II position was obtained by firmly placing disposable electrodes over the nonhairy, cleaned skin at three sites: right wrist (–ve lead), left foot (+ve lead), and right foot (ground lead). HRV recording was done for 10 minutes. From the recording, 5-minute ECG segments were selected for analysis of HRV in all subjects after ruling out gross ECG abnormalities, if any, and the auto-computed results were analyzed for the time- and frequency-domain parameters of HRV.[11,12] Time-domain measures and frequency-domain measures of HRV are summarized in Tables 1 and 2.

Time Domain Measures

Frequency Domain Methods

Statistical Analysis

The data were analyzed using International Business Machines (IBM) Statistical Package for the Social Sciences (SPSS) version 26.0. Descriptive analysis was performed. After testing assumptions for correlational analysis between HRV variables and sleep parameters, Pearson's correlation coefficient test was used; otherwise, the Spearman correlation test was used.

Results

Demographic Characteristics

Out of 84 participants, the proportion of male and female students was 54 (64.28%) and 30 (35.71%), respectively. The average age of participants was 20.19 ± 1.36 [mean ± standard deviation (SD)], with an average BMI of 21.76 ± 1.86 kg/m^2. Table 3 shows the demographic characteristics of participants. The proportion of good sleepers (PSQI global scores <5) was 20 (23.81%), and poor sleepers (PSQI global scores ≥5) were 64 (76.19%).

Descriptive Statistics

Table 4 shows the mean values of PSQI global scores and its seven components, and HRV variables. The mean PSQI global score was 6.44 (SD = 2.62). Sleep duration, sleep latency, daytime dysfunction, and subjective sleep quality had means above 1, contributing most to the overall PSQI score. Sleep disturbance, sleep efficiency, and the use of sleep medication had means below 1.

The majority of participants (n = 63, 75.00%) had >85% sleep efficiency. The results of sleep latency showed that one-third of the participants (n = 29, 34.52%) took 16–30 minutes to fall asleep. Among the 84 participants, more than half (n = 51, 60.71%) rated their sleep quality as fairly good. The majority of participants (n = 76, 90.47%) complained of daytime dysfunction.

Table 1: Time domain parameters

SDRR (ms)	Standard deviation of the R-R intervals	Reflects total HRV
RMSSD (ms)	Root square of the mean of the sum of the squares of differences between adjacent RR intervals	With normal sinus rhythm reflects vagal activity
pRR50 (%)	Percentage of RR intervals >50 ms different from previous (RR)	With normal sinus rhythm reflects vagal activity

ms, milliseconds

Table 2: Frequency domain parameters

Frequency bands	*Frequency*		*Mediated by*
Low frequency (LF) n.u.	0.04–0.15 Hz	[LF/(TP-VLF), some calculate LF/(LF + HF)]	Reflect sympathetic activity
High frequency (HF) n.u.	0.15–0.4 Hz	[HF/(TP-VLF), some calculate HF/(LF + HF)]	Reflect parasympathetic activity
LF/HF ratio			Sympatho-vagal balance

n.u., normalized unit; TP, total power; VLF, very low frequency;

Assumption Testing

HRV variables and PSQI scores were assessed for normality. Data followed a normal distribution as determined from skewness, kurtosis, and the Z test (skewness and kurtosis), except for sleep disturbance, sleep efficiency, sleep medication, and LF/HF.[13] LF/HF was log-transformed. A few outliers were present in the data, which were replaced with the 5th or 95th percentile values.

Correlation between Heart Rate Variability and Sleep Parameters

Table 5 shows the correlation between sleep and HRV parameters. There was a statistically significant negative correlation between PSQI global score and HF (r = −0.358, p < 0.01), RMSSD (r = −0.227, p < 0.05), and pRR50 (r = −0.288, p < 0.01). A statistically significant positive correlation between PSQI global score and LF/HF (r = 0.390, p < 0.01) and LF (r = 0.375, p < 0.01) was found. SDRR (r = −0.223, p < 0.05), RMSSD (r = −0.258, p < 0.05), and pRR50 (r = −0.242, p < 0.05) correlated significantly and negatively with subjective sleep quality.

Discussion

The present study examined the association between sleep quality indices and HRV parameters. Global PSQI scores were found to be negatively correlated with RMSSD, pRR50, and HF. LF and LF/HF ratio were found to be positively correlated with global PSQI scores.[11]

The above findings indicate that the poorer the sleep quality, the less is the parasympathetic activity and the more is the sympathetic activity. This is consistent with the study by Cvejic et al. (2018), which found poor sleep was associated with reduced nocturnal parasympathetic activity in medical students.[14] Studies in other population groups also found that parasympathetic-related HRV indices were reduced with sleep problems.[12,15,16] In contrast, Guo et al. (2022), utilizing 24-hour

Table 3: Demographic characteristics of participants

Variables	
Gender (%)	Male 54 (64.28%), female 30 (35.71%)
Age (mean ± SD) in years	20.19 ± 1.36
BMI (mean ± SD) in kg/m^2	21.76 ± 1.86
Participants with good sleep (global score <5)	20 (23.81%)
Participants with poor sleep (global score >5)	64 (76.19%)

SD, standard deviation

Table 4: HRV parameters, mean global, and component PSQI scores

Variable		*Numbers (percentage, %)*	*Mean (SD)*
Sleep duration (hours)			1.39 (0.95)
	>7	16 (19.04)	
	6–7	31 (36.90)	
	5–6	25 (29.76)	
	<5	12 (14.28)	
Sleep disturbance			0.87 (0.33)
	Never	11 (13.09)	
	Once or twice	73 (86.90)	
Sleep latency (minutes)			1.32 (0.95)
	<15	19 (22.62)	
	16–30	29 (34.52)	
	31–60	26 (30.95)	
	>60	10 (11.90)	
Daytime dysfunction			1.46 (0.79)
	0	8 (9.52)	
	1–2	37 (44.04)	
	3–4	31 (36.90)	
	5–6	8 (9.52)	
Sleep efficiency (%)			0.36 (0.72)
	>85	63 (75.00)	
	75–84	15 (17.86)	
	65–74	3 (3.57)	
	<65	3 (3.57)	
Sleep quality			1.12 (0.70)
	Very good	13 (15.48)	
	Fairly good	51 (60.71)	
	Fairly bad	17 (20.23)	
	Very bad	3 (3.57)	
Use of sleep medication			0.02 (0.21)
	Not during the past	83 (98.80)	
	Once or twice a week	1 (1.19)	
PSQI global score			6.44 (2.62)
Time domain parameters			
SDRR (ms)			148.05 (18.46)
RMSSD (ms)			48.69 (18.43)
pRR50 (%)			26.72 (16.82)
Frequency domain parameters			
LF (n.u.)			44.44 (15.99)
HF (n.u.)			53.37 (14.87)
LF/HF			1.00 (0.72)

SD, standard deviation

HRV indicators in medical students, did not find a difference between groups of sleep quality.[8]

SDRR, RMSSD, and pRR50 were also found to be inversely correlated with subjective sleep quality. In addition, SDRR was inversely correlated with sleep efficiency and was significantly and positively correlated with daytime dysfunction. These findings suggest that higher values in parasympathetic indices (RMSSD and pRR50) are associated with very/fairly good sleep quality and higher sleep efficiency (% sleep, hours slept, and hours spent in bed after sleep onset). These findings are consistent with Sajjadieh et al. (2020), who found lower SDRR correlated with sleep quality indices (bad subjective sleep quality, poor sleep efficiency, very high daytime dysfunction).[17] A study by Cosgrave et al. (2020) found that poor sleepers with short sleep duration had significantly lower SDRR compared to good sleepers.[18]

Various studies have demonstrated that poor sleep can produce reduced parasympathetic activity and may affect the ability of ANS to inhibit sympathetic activity.[3,19,20] Dettoni et al. (2012) showed that mild sleep restriction for a few nights resulted in increased sympathetic activity.[3] A study by Bourdillon et al. (2021) found decreased parasympathetic and increased sympathetic activity in healthy adults with partial sleep deprivation.[21]

Although we did not measure stress levels in the participants, one major cause of poor sleep quality is the perception of stress. Cvejic et al. (2018) found that poor sleep was associated with psychological distress and reduced nocturnal HRV.[14] Hall et al. (2004) utilized a standard speech task paradigm to elicit stress before sleep and found decreased parasympathetic activity. These studies suggest that changes in HRV due to stress may be associated with poor sleep.[22]

In this study, the mean total PSQI score was 6.44 (SD = 2.62). This finding is consistent with the pooled mean total PSQI score of 6.1 (95% CI: 5.6–6.5) across 41 studies.[23] The PSQI subscale means suggest that sleep duration, sleep latency, daytime dysfunction, and subjective sleep quality contributed most to the PSQI global scores. These findings align with other studies (Brick et al. 2010, Ahrberg et al. 2012, Rao et al. 2020), which also highlighted that subjective sleep quality, sleep duration, sleep latency, sleep disturbance, and daytime dysfunction play a significant role in elevating the PSQI global scores in medical students.[2,23,24]

The present study found that 71% of participants were sleeping <7 hours per night on average, which is below the recommendation of at least 7 hours per night (National Sleep Foundation recommendation for young adults).[25] Academic pressure, poor sleep hygiene, staying away from home, academic year, low physical activity, and taking naps during the daytime were found to be associated with poor sleep in medical students.[2,20,26]

In order to keep up with their academic workloads, many students sacrifice sleep or delay sleep for immediately rewarding activities.[14,27] However, abstaining from sleep could potentially hinder their learning outcomes in the immediate future while also affecting their overall health and effectiveness as medical practitioners in the long run.[14,19,22]

Limitations

The current study had a few limitations. First, sleep was assessed through a self-reported questionnaire. Although the PSQI is a well-validated tool, it is still subjective

Table 5: Correlation among sleep parameters and HRV ($n = 84$)

	Sleep duration	*#Sleep disturbance*	*Sleep latency*	*Sleep daytime dysfunction*	*#Sleep efficiency*	*Sleep quality*	*#Sleep medication*	*Total PSQI*
SDRR	0.122	−0.020	−0.040	0.223*	−0.219*	−0.223*	−0.043	−0.087
RMSSD	0.079	0.055	−0.010	0.147	−0.165	−0.258*	−0.123	−0.227*
pRR50	0.045	0.033	−0.003	0.114	−0.161	−0.242*	−0.130	−0.288**
LF	−0.075	0.092	0.011	0.016	0.082	0.021	0.054	0.375**
HF	0.133	−0.124	−0.023	−0.038	−0.095	−0.031	−0.049	−0.358**
LF/HF (log)	−0.090	0.108	0.016	0.002	0.076	0.042	0.056	0.390**

**p-value < 0.01 (2-tailed); *p-value < 0.05 (2-tailed); #Spearman's rank-order correlation

in nature. This study was correlational in nature; hence, causal inferences cannot be determined. The cross-sectional design hinders tracking changes in sleep quality in medical students over time. Further studies with more thorough screening of individuals, including assessments of psychological health and sleep attitudes with objective sleep outcomes, are warranted.

Conclusion

This study found a significant correlation between poor sleep in medical students and altered HRV, indicating a potential imbalance in ANS activity. The prevalence of inadequate sleep and higher PSQI scores emphasizes the need for interventions to address sleep patterns among medical students, which is crucial for both academic performance and long-term well-being.

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Orcid

Kaushal Kumar Alam https://orcid.org/0000-0002-9082-0840

References

1. Tahmasian M, Samea F, Khazaie H, et al. The interrelation of sleep and mental and physical health is anchored in grey-matter neuroanatomy and under genetic control. Commun Biol 2020;3(1):1–13.
2. Brick CA, Seely DL, Palermo TM. Association between sleep hygiene and sleep quality in medical students. Behav Sleep Med 2010;8(2):113–121.
3. Dettoni JL, Consolim-Colombo FM, Drager LF, et al. Cardiovascular effects of partial sleep deprivation in healthy volunteers. J Appl Physiol 2012;113(2):232–236.
4. Nagai M, Hoshide S, Kario K. Sleep duration as a risk factor for cardiovascular disease—a review of the recent literature. Curr Cardiol Rev 2010;6(1):54–61.
5. Hsu HC, Lee HF, Lin MH. Exploring the association between sleep quality and heart rate variability among female nurses. Int J Environm Res Public Heal 2021;18(5551):1–13.
6. Shaffer F, Meehan ZM, Zerr CL. A critical review of ultra-short-term heart rate variability norms research. Front Neurosci 2020;14(11):1–11.
7. Chalmers T, Hickey BA, Newton P, et al. Associations between sleep quality and heart rate variability; implications for a biological model of stress detection using wearable technology. Int J Environ Res Public Health 2022;19(9):1–10.
8. Guo X, Su T, Xiao H, et al. Using 24-h heart rate variability to investigate the sleep quality and depression symptoms of medical students. Front Psychiatry 2022;12(1):1–10.
9. Faul F, Erdfelder E, Lang AG, et al. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007;39(2):175–191.
10. Buysse DJ, Reynolds CF, Monk TH, et al. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res 1989;28:193–213.
11. Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Circulation 1996;93(5):1043–1605.
12. Stein PK, Pu Y. Heart rate variability, sleep and sleep disorders. Sleep Med Rev 2012;16(1):47–66.
13. Kim HY. Statistical notes for clinical researchers: assessing normal distribution (2) using skewness and kurtosis. Restor Dent Endod 2013;38(1):52–54.
14. Cvejic E, Huang S, Vollmer-Conna U. Can you snooze your way to an 'A'? Exploring the complex relationship between sleep, autonomic activity, wellbeing and performance in medical students. Aust N Z J Psychiatry 2018;52(1):39–46.
15. Yang AC, Tsai SJ, Yang CH, et al. Reduced physiologic complexity is associated with poor sleep in patients with major depression and primary insomnia. J Affect Disord 2011;131(1–3):179–185.
16. Bonnet MH, Arand DL. Heart rate variability in insomniacs and matched normal sleepers. Psychosom Med 1998;60(5):610–615.
17. Sajjadieh A, Shahsavari A, Safaei A, et al. The association of sleep duration and quality with heart rate variability and blood pressure. Tanaffos 2020;19(2):135–143.
18. Cosgrave J, Phillips J, Haines R, et al. Revisiting nocturnal heart rate and heart rate variability in insomnia: a polysomnography-based comparison of young self-reported good and poor sleepers. J Sleep Res 2021;30(4):1–12.
19. Castro-Diehl C, Diez Roux AV, Redline S, et al. Sleep duration and quality in relation to autonomic nervous system measures: the multi-ethnic study of atherosclerosis (MESA). Sleep 2016;39(11):1927–1940.
20. Oliver MD, Baldwin DR, Datta S. The relationship between sleep and autonomic health. J Am Coll Heal 2021;68(5):550–556.
21. Bourdillon N, Jeanneret F, Nilchian M, et al. Sleep deprivation deteriorates heart rate variability and photoplethysmography. Front Neurosci 2021;15:1–12.
22. Hall M, Vasko R, Buysse D, et al. Acute stress affects heart rate variability during sleep. Psychosom Med 2004;66(1):56–62.
23. Rao WW, Li W, Qi H, et al. Sleep quality in medical students: a comprehensive meta-analysis of observational studies. Sleep Breath 2020;24(3):1151–1165.
24. Ahrberg K, Dresler M, Niedermaier S, et al. The interaction between sleep quality and academic performance. J Psychiatr Res 2012;46(12):1618–1622.
25. Hirshkowitz M, Whiton K, Albert SM, et al. National Sleep Foundation's updated sleep duration recommendations: final report. Sleep Heal 2015;1(4):233–243.
26. Almojali AI, Almalki SA, Alothman AS, et al. The prevalence and association of stress with sleep quality among medical students. J Epidemiol Glob Health 2019;7(2):169–174.
27. Gomes AA, Tavares J, De Azevedo MHP. Sleep and academic performance in undergraduates: a multi-measure, multi-predictor approach. Chronobiol Int 2011;28(9):786–801.