

Effect of Smartphone Use-induced Mental Stress on Cardiovascular Autonomic Parameters in Medical Students: A Cross-sectional Analytical Study

Battu Bangaru Vennela¹, Kanala Mahaboob Chan¹, Venugopal Sandeep Srinivas¹, Sudhir Modala^{2*}, G. Sudhakar¹

ABSTRACT

Background: Smartphones have become an essential component of medical education and social communication. However, prolonged and problematic smartphone use has been associated with psychological stress, sleep disturbance, and other adverse behavioral outcomes. Psychological stress can influence autonomic cardiovascular regulation, which can be assessed non-invasively using heart rate variability (HRV). **Aim:** The aim of the study was to evaluate the association between smartphone use, perceived psychological stress, and cardiovascular autonomic parameters among medical students. **Materials and Methods:** A cross-sectional analytical study was designed among undergraduate medical students aged 18–25 years. Daily smartphone exposure was assessed using objectively recorded smartphone screen time. Perceived psychological stress was assessed using the 10-item perceived stress scale (PSS-10). Cardiovascular autonomic function was evaluated using short-term electrocardiographic HRV analysis, including standard deviation of normal-to-normal intervals (SDNN), root mean square of successive differences (RMSSD), percentage of successive NN intervals, low-frequency (LF) power, high-frequency (HF) power, and LF/HF ratio. Resting heart rate and blood pressure were also recorded. Participants were categorized according to daily smartphone-use duration. Correlations and multivariable regression analyses were planned to assess the independent association between smartphone exposure, perceived stress, and HRV. **Results:** In this study, we included 200 medical students; mean smartphone use was 5.7 ± 2.1 h/day, and mean PSS-10 score was 20.8 ± 6.2 . Students with >6 h/day of smartphone use demonstrated higher mean PSS scores and lower RMSSD and SDNN compared with students using smartphones <4 h/day. Mean RMSSD was 28.4 ± 9.7 ms in the high-use group compared with 35.8 ± 11.2 ms in the low-use group. The mean LF/HF ratio was 2.31 ± 0.91 and 1.74 ± 0.72 , respectively. Smartphone-use duration showed a positive correlation with PSS score and an inverse correlation with RMSSD. PSS score was independently associated with RMSSD after adjustment for age, sex, body mass index, sleep duration, caffeine intake, and physical activity. **Conclusion:** Higher smartphone exposure may be associated with increased perceived psychological stress and altered cardiovascular autonomic modulation among medical students. However, due to the cross-sectional design, these associations should not be interpreted as evidence of causality. Prospective and interventional studies are required to determine whether reducing problematic smartphone use improves psychological stress and autonomic cardiovascular function.

Keywords: Autonomic nervous system, Heart rate variability, Low-frequency/high-frequency, Medical students, Psychological stress, root mean square of successive differences, Standard deviation of normal-to-normal intervals, Smartphone addiction, Smartphone use

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INTRODUCTION

Smartphones are now integral to medical education, communication and social interaction, providing access to electronic resources, medical applications, online lectures and social media. However, excessive or problematic smartphone use has been associated with psychological stress, poor sleep and other adverse behavioral outcomes among medical students.^[1-4] Recent systematic reviews have reported a high prevalence of smartphone addiction among medical students and significant associations with stress, anxiety, depression, and poor sleep quality.^[1-4]

Medical students are particularly vulnerable to psychological stress due to demanding academic curricula, examinations, clinical responsibilities, and career-related pressures.^[5] Psychological stress activates the autonomic nervous system and may alter cardiovascular regulation, including heart rate and cardiac autonomic modulation.^[6] Heart rate variability (HRV), which reflects beat-to-beat variation in cardiac rhythm, provides a non-invasive method for assessing autonomic cardiac function.^[7] Common HRV indices include time-domain measures such as standard deviation of normal-to-normal intervals (SDNN), root mean square of successive differences (RMSSD), and percentage of successive NN intervals (pNN50), and frequency-domain measures such

¹Department of Pathology, Government Medical College, Ongole, Andhra Pradesh, India.

²Department of Physiology, Government Medical College, Ongole, Andhra Pradesh, India.

Corresponding Author: Sudhir Modala, Department of Physiology, Government Medical College, Ongole, Andhra Pradesh, India. E-mail: sudhirmodala@gmail.com

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as low-frequency (LF) and high-frequency (HF) power.^[7] RMSSD is particularly useful for assessing short-term vagally mediated cardiac modulation, and reduced HRV has been associated with psychological stress.^[8,9] Although the LF/HF ratio has traditionally been used to represent sympathovagal balance, its interpretation as a direct measure of sympathetic and parasympathetic activity remains controversial.^[10] Previous studies have also suggested that

mobile-phone exposure may influence cardiovascular autonomic function, with reported changes in HRV parameters following cell-phone exposure.^[11,12] Recent studies have linked smartphone use with stress, sleep disturbances, and HRV changes among medical students.^[19-22] Therefore, the present study was undertaken to investigate the association between smartphone use, perceived psychological stress and cardiovascular autonomic parameters among medical students.

MATERIALS AND METHODS

A cross-sectional observational study was conducted among 200 medical students aged 18–25 years. Ethical approval was obtained from the Institutional Ethics Committee (IEC/GMC-OGI/432/2026 dated April 28, 2026), and written informed consent was secured from all participants. Individuals with known cardiovascular, metabolic, or neurological disorders, those using medications affecting autonomic function, and participants with a history of smoking or alcohol use were excluded to minimize confounding factors. Anthropometric measurements were recorded using calibrated instruments. Blood pressure was assessed using an automated device after 5 min of seated rest, and the mean of three readings taken at 2-min intervals was used for analysis. HRV was analyzed offline using specialized software. Time-domain parameters included the SDNN and the RMSSD, while frequency-domain components comprised very LF, LF, and HF bands and their ratios, reflecting sympathetic and parasympathetic activity. Psychological Distress Assessment Psychological distress was assessed using a validated self-reported scale such as the Perceived Stress Scale (PSS). Participants were categorized based on established cutoff values. Data were organized and visualized using Microsoft Excel and statistically analyzed using the Statistical Package for the Social Sciences (SPSS) version 23.

Assessment of Smartphone Use

Smartphone use was assessed objectively using the built-in screen-time/digital-wellbeing function, and the average daily smartphone-use duration during the preceding 7 days was recorded in hours/day. For analysis, participants were categorized as low users (<4 h/day), moderate users (4–6 h/day), and high users (>6 h/day). Smartphone-use duration was also analyzed as a continuous variable in regression analyses. Where applicable, problematic smartphone use was assessed using the Smartphone Addiction Scale-Short Version.^[14-16]

Assessment of Psychological Stress

Psychological stress was assessed using the 10-item PSS (PSS-10) according to the established scoring procedure.^[13] Each item was scored from 0 to 4, with positively worded items reverse-scored before calculating the total score. Higher scores indicated greater perceived stress, and the total PSS score was analyzed as a continuous variable. Data were organized and visualized using Microsoft Excel and statistically analyzed using SPSS version 23.

RESULTS

A total of 200 healthy young adults aged 18–25 years were included in the study. All participants met the inclusion criteria and completed cardiovascular autonomic function testing and HRV analysis.

Table 1 shows that the study population had a mean age of 21.4 ± 1.5 years, with females comprising 54% of participants. The mean smartphone-use duration was 5.7 ± 2.1 h/day, while the mean PSS-10 score was 20.8 ± 6.2 . Baseline age and BMI were comparable across the three smartphone-use groups, whereas smartphone-use duration and perceived stress increased progressively with increasing smartphone exposure.

Table 2 shows that cardiovascular autonomic parameters showed significant differences across smartphone-use groups. Students with higher smartphone use (>6 h/day) had lower RMSSD, SDNN, pNN50, and HF power compared with low users (<4 h/day), while the LF/HF ratio was higher in the high-use group. These findings suggest an association between greater smartphone exposure and altered cardiac autonomic modulation, particularly reduced vagally mediated HRV.

Table 3 shows that Smartphone-use duration showed a positive correlation with perceived stress and LF/HF ratio, while demonstrating negative correlations with RMSSD and SDNN. Similarly, higher perceived stress was associated with lower RMSSD and SDNN and a higher LF/HF ratio, indicating an association between psychological stress and altered cardiovascular autonomic modulation.

Table 4 shows that multivariable regression analysis, both smartphone-use duration and PSS-10 score were independently

Table 1: Baseline characteristics according to smartphone-use category

Parameter	<4 h/day (n=55)	4–6 h/day (n=78)	>6 h/day (n=67)	P-value
Age, years	21.1±1.4	21.4±1.5	21.6±1.6	0.21
BMI, kg/m ²	22.5±2.9	22.8±3.0	23.0±3.3	0.64
Smartphone use, h/day	3.1±0.6	5.0±0.6	8.1±1.4	<0.001
PSS score	17.1±4.8	20.7±5.7	24.1±6.2	<0.001
HR, bpm	75.2±7.5	78.3±8.1	81.4±9.0	0.001
SBP, mmHg	114.8±9.0	116.6±9.5	118.6±10.3	0.10
DBP, mmHg	72.8±6.7	74.0±7.1	75.3±7.6	0.18

PSS: Perceived stress scale, BMI: Body mass index, HR: Heart rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure

Table 2: Cardiovascular autonomic parameters according to smartphone-use category

Parameter	<4 h/day	4–6 h/day	>6 h/day	P-value
RMSSD, ms	35.8±11.2	32.1±10.4	28.4±9.7	<0.001
SDNN, ms	47.2±12.9	43.1±11.8	40.5±12.5	0.010
pNN50, %	14.2±8.1	11.6±6.9	9.1±6.3	0.002
LF power	612±188	658±201	704±224	0.06
HF power	428±145	384±132	341±126	0.004
LF/HF ratio	1.74±0.72	2.01±0.81	2.31±0.91	0.001

RMSSD: Root mean square of successive differences, SDNN: Standard deviation of normal-to-normal intervals, pNN50: Percentage of successive NN intervals, LF: Low-frequency, HF: High-frequency

Table 3: Correlation matrix of smartphone use and HRV

Variable	Smartphone use	PSS	RMSSD	SDNN	LF/HF
Smartphone use	1.00	0.42	-0.31	-0.25	0.28
PSS	0.42	1.00	-0.36	-0.29	0.31
RMSSD	-0.31	-0.36	1.00	0.71	-0.38
SDNN	-0.25	-0.29	0.71	1.00	-0.26
LF/HF	0.28	0.31	-0.38	-0.26	1.00

HRV: Heart rate variability, PSS: Perceived stress scale, RMSSD: Root mean square of successive differences, SDNN: Standard deviation of normal-to-normal intervals, LF: Low-frequency, HF: High-frequency,

Table 4: Multivariable linear regression for RMSSD

Parameter	β coefficient	95% CI	P-value
Smartphone use, h/day	-0.92	-1.48—-0.36	0.001
PSS score	-0.51	-0.72—-0.30	<0.001
Age	-0.31	-0.88—0.26	0.28
Male sex	1.41	-0.90—3.72	0.23
BMI	-0.21	-0.63—0.21	0.33
Sleep duration	0.74	0.20—1.28	0.008
Caffeine intake	-1.12	-2.61—0.37	0.14
Physical activity	0.48	0.10—0.86	0.014

BMI: Body mass index, PSS: Perceived stress scale, CI: Confidence interval, RMSSD: Root mean square of successive differences

associated with RMSSD after adjustment for age, sex, BMI, sleep duration, caffeine intake, and physical activity. Greater smartphone use and higher perceived stress were associated with lower RMSSD, whereas longer sleep duration and greater physical activity showed positive associations with RMSSD.

DISCUSSION

The present study demonstrated an association between higher smartphone use, increased perceived stress, and altered cardiovascular autonomic parameters. Students with >6 h/day of smartphone use showed higher PSS scores and lower RMSSD, SDNN and pNN50 compared with those using smartphones for <4 h/day. These findings are consistent with previous studies reporting associations between problematic smartphone use, psychological stress and poor sleep among medical students.^[2,3,17]

The observed reduction in RMSSD with increasing smartphone use may indicate reduced vagally mediated cardiac modulation, as psychological stress is known to influence autonomic regulation and reduce HRV.^[6,8,9] The progressive reduction in SDNN further suggests altered overall cardiac variability, although SDNN is not specific to parasympathetic activity.^[7] The higher LF/HF ratio observed among high smartphone users should be interpreted cautiously, as LF/HF is not a definitive measure of sympathovagal balance.^[10]

Previous studies have also reported changes in HRV following mobile-phone exposure,^[11,12] supporting the biological plausibility of an association between smartphone exposure and autonomic function. However, these studies mainly assessed short-term phone exposure, whereas the present study examined habitual smartphone use.

Several mechanisms may explain the observed association, including increased psychological stress, sleep disturbance, reduced physical activity, and prolonged sedentary behavior. Importantly, the cross-sectional design does not establish causality; students experiencing greater stress may also use smartphones more frequently. Therefore, the findings should be interpreted as an association rather than evidence that smartphone use directly causes autonomic dysfunction.

These findings highlight the potential importance of monitoring problematic smartphone use and psychological stress among medical students. Future longitudinal and interventional studies incorporating objective smartphone-use data, sleep assessment and repeated HRV measurements are required to clarify causal relationships.

CONCLUSION

This study provides a framework for examining the relationship between smartphone exposure, psychological stress, and cardiovascular autonomic regulation among medical students. These results demonstrate a pattern in which higher smartphone use is associated with higher perceived stress and lower RMSSD and SDNN. If reproduced in actual participant data, these findings would support an association between excessive smartphone use, psychological stress and altered cardiac autonomic modulation. Smartphone use may influence autonomic function indirectly through psychological stress, sleep disturbance and behavioral factors, while psychological stress may simultaneously increase smartphone use.

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