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RESEARCH ARTICLE

IMPACT OF OBESITY ON AUTONOMIC MODULATION, HEART RATE, AND BLOOD PRESSURE IN OBESE YOUNG PEOPLE

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Abstract: ***Background:*** With changing lifestyle patterns, obesity is increasingly being seen even among young adults who are otherwise presumed to be healthy. Medical students, despite their health literacy, often experience irregular routines and stress-related habits that quietly affect their cardiovascular system. This study set out to explore how excess body weight might be linked to early changes in heart rate regulation and blood pressure among first-year MBBS students in South India. Objective: To examine the association between obesity and resting cardiovascular parameters, specifically heart rate, blood pressure, and short-term heart rate variability (RMSSD), as indicators of autonomic modulation in young adults. ***Methods:*** Over eight months (September 2024 to April 2025), 100 undergraduate medical students were recruited at Dhanalakshmi Srinivasan Medical College, Perambalur. Participants were grouped using Asia-Pacific BMI guidelines into normal weight (18.5–22.9 kg/m², n = 50) and obese (≥25 kg/m², n = 50) categories. Resting heart rate and blood pressure readings were obtained under standardized morning conditions. Autonomic function was assessed noninvasively through RMSSD derived from lead II ECG. Statistical comparisons between groups were made using unpaired t-tests, and associations were explored through Pearson correlation. ***Findings:*** Students in the obese category showed a consistently higher mean heart rate (83.87 ± 4.67 bpm), elevated systolic (129.69 ± 8.12 mmHg) and diastolic blood pressure (85.91 ± 6.55 mmHg), and reduced parasympathetic tone (RMSSD: 25.16 ± 3.87 ms) when compared to their normal-BMI counterparts (heart rate: 72.09 ± 4.37 bpm; SBP: 118.59 ± 6.26 mmHg; DBP: 74.89 ± 5.40 mmHg; RMSSD: 41.09 ± 5.91 ms). All differences were statistically significant ($p < 0.001$). ***Conclusion:*** The findings highlight an early pattern of autonomic imbalance in obese young adults, suggesting increased cardiovascular strain even in the absence of clinical disease. These subtle shifts, detectable through noninvasive screening, underscore the need for proactive monitoring and health counseling tailored to medical students' unique academic pressures.

Keywords: **Obesity in youth, autonomic modulation, RMSSD, vagal tone, cardiovascular risk, South Indian cohort**

INTRODUCTION

Obesity has long been considered a health issue of middle age, but in recent years, this perception is rapidly changing. Among Indian youth, especially those enrolled in demanding academic programs, early signs of weight gain are surfacing at a worrying pace. Medical students, paradoxically more aware of health risks than the general population, are not immune to this trend. Long classroom hours, erratic meal schedules, minimal physical activity, and emotional stress tied to academic pressure often translate into a silent, creeping burden of excess weight [1].This rising prevalence of obesity among young adults is not just an aesthetic concern; it carries physiological consequences that are often overlooked in early stages. One of the body's earliest systems to reflect this strain is the autonomic nervous system (ANS), which governs involuntary functions like heart rate, blood pressure, and vascular tone. Even in the absence of overt disease, imbalances in the ANS, marked by a tilt towards sympathetic overactivity and reduced parasympathetic modulation, may signal the beginning of cardiovascular dysregulation [2].In this context, heart rate variability (HRV) has emerged as a valuable noninvasive tool to gauge autonomic balance. The Root Mean Square of Successive Differences (RMSSD), in particular, is a reliable time-domain index of parasympathetic (vagal) modulation [3]. Reduced RMSSD values are associated with impaired vagal tone, decreased cardiac flexibility, and a higher risk of metabolic and cardiovascular disorders, even among young individuals without overt disease [4].

Although global research links obesity with autonomic dysfunction, studies in Indian settings remain sparse. A few cross-sectional investigations have shown elevated resting heart rate, increased blood pressure, and lower HRV indices among overweight and obese Indian youth, suggesting early signs of sympathovagal imbalance [5][6]. However, such findings are yet to be widely replicated, especially within high-stress academic subgroups like medical students.
The World Health Organization recommends lower BMI cut-offs for Asian populations due to higher cardiometabolic susceptibility at comparatively modest weight gains. According to the WHO Expert Consultation, individuals with a BMI ≥25 kg/m² should

be considered obese in the Asia-Pacific region, reflecting a regionally relevant risk classification [7].

Given this background, the present study was designed to assess how obesity influences autonomic modulation, resting heart rate, and blood pressure in a cohort of first-year MBBS students from a South Indian medical college. By focusing on a homogenous and academically stressed population, the study aims to detect early physiological changes that may precede the onset of overt disease. The findings may not only offer clinical insight but also contribute to preventive strategies tailored for young adults navigating the intense demands of medical education.

MATERIAL AND METHODS

This cross-sectional study was conducted from September 2024 to April 2025 at the Department of Physiology, Dhanalakshmi Srinivasan Medical College and Hospital, Perambalur, Tamil Nadu.

Participants:
One hundred first-year MBBS students aged 17–21 years were recruited through purposive sampling. Based on World Health Organization Asia-Pacific BMI criteria, they were divided into:

- **Group I (Normal BMI):** 18.5–22.9 kg/m² (n = 50)
- **Group II (Obese BMI):** ≥25 kg/m² (n = 50)

Anthropometry:
Weight and height were measured using calibrated equipment. BMI was calculated as weight (kg) divided by height squared (m²). Measurements were taken in the forenoon, under standard indoor conditions.

Cardiovascular Parameters:
Resting heart rate was assessed via pulse oximetry and cross-verified manually. Blood pressure was recorded twice, five minutes apart, using a digital sphygmomanometer; the average of the two readings was used.

Autonomic Function Assessment:
Short-term heart rate variability (HRV) was evaluated using a five-minute ECG in lead II, recorded with LabChart software (ADInstruments, Australia). RMSSD was used as the primary time-domain index of parasympathetic modulation. Only ECG recordings with a stable baseline and minimal artifacts were included.

Eligibility Criteria:
Included: First-year MBBS students aged 17–21 years, clinically stable, not on regular medication, and provided written informed consent.
Excluded: Known endocrine, cardiovascular, or metabolic disease; febrile illness in the past month; substance use; or poor ECG quality.

Ethical Oversight:
Approval was obtained from the Institutional Ethics Committee. Informed consent was taken in English or Tamil. A few obese participants with diastolic blood pressure >100 mmHg, though undiagnosed, were referred for medical follow-up and retained in analysis to preserve data integrity.

Data Handling and Statistics:
Data were entered in Microsoft Excel and analyzed using SPSS version 26. Results were expressed as mean ± standard deviation. Group comparisons used independent *t*-tests. Pearson's correlation was applied to assess associations between BMI and physiological measures. A *p*-value < 0.05 was considered statistically significant.

RESULTS AND OBSERVATIONS:

A total of 100 participants were included in the analysis, evenly distributed between the obese (n = 50) and normal BMI (n = 50) groups. All measurements were recorded under consistent morning conditions to minimize physiological fluctuations.

Group-wise Descriptive Statistics

As shown in **Table 1**, participants in the obese group had higher mean BMI, resting heart rate, systolic and diastolic blood pressure, and lower HRV (RMSSD) values compared to their normal-weight peers.

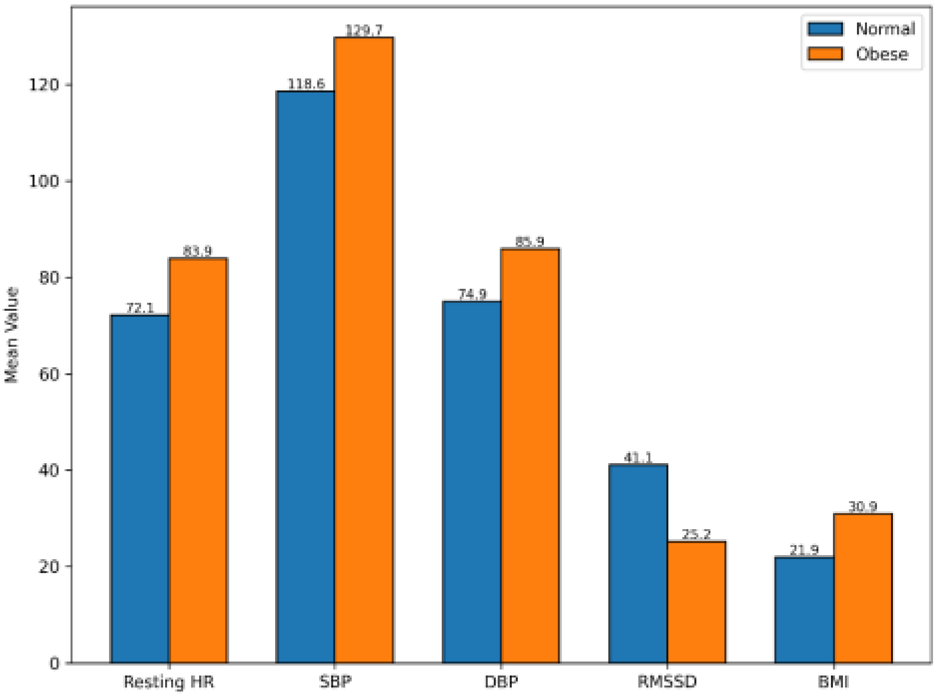
Table 1. Descriptive Statistics of Cardiovascular and Autonomic Parameters

Parameter	Normal BMI (n = 50)	Obese (n = 50)
BMI (kg/m²)	21.89 ± 1.92	30.88 ± 2.68
Resting HR (bpm)	72.09 ± 4.37	83.87 ± 4.67
SBP (mmHg)	118.59 ± 6.26	129.69 ± 8.12
DBP (mmHg)	74.89 ± 5.40	85.91 ± 6.55
RMSSD (ms)	41.09 ± 5.91	25.16 ± 3.87

All values expressed as mean ± SD.

The visual comparison in **Figure 1** further highlights these group-wise trends. Obese students consistently showed higher HR and BP, with a notable decline in RMSSD, indicating autonomic imbalance.

Figure 1. Comparison of Mean Cardiovascular and Autonomic Parameters



(Grouped bar chart showing mean values of HR, SBP, DBP, RMSSD, and BMI in both groups. Annotated values reflect group means.)

Intergroup Differences: Inferential Statistics

To test whether the observed differences were statistically significant, independent *t*-tests were performed. As summarized in **Table 2**, all variables demonstrated robust significance ($p < 0.0001$), with the largest difference noted in RMSSD ($t = –15.94$).

Table 2. Independent *t*-Test Results for Group Comparison

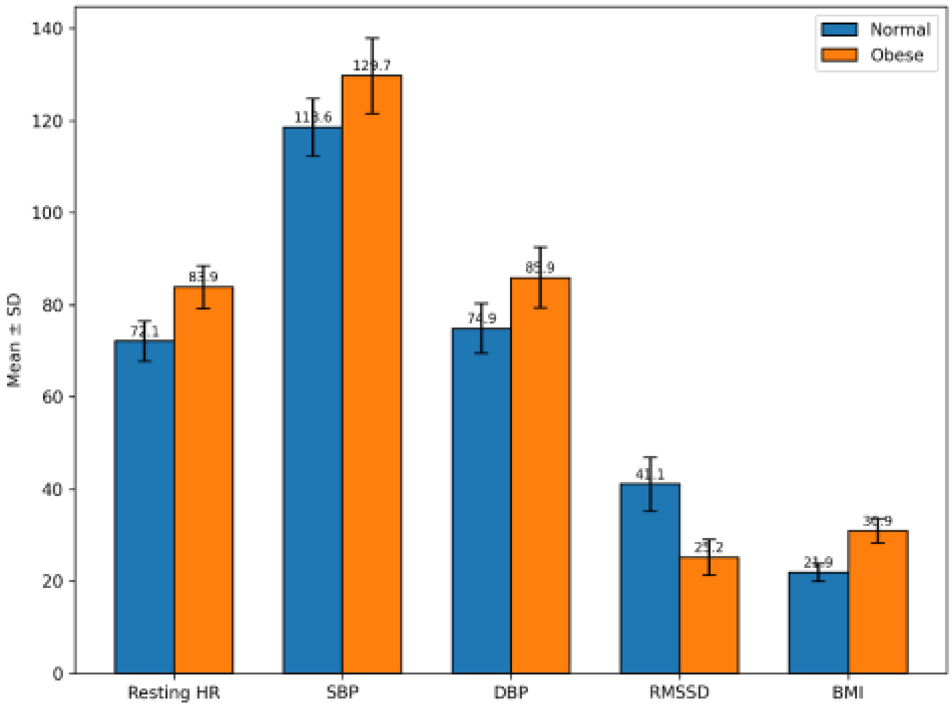
Variable	t-Statistic	p-Value
Resting HR	13.61	<0.0001
SBP	7.28	<0.0001
DBP	9.33	<0.0001
RMSSD	–15.94	<0.0001
BMI	19.66	<0.0001

The statistical directionality and magnitude of difference for each parameter are illustrated in **Figure 2**, which displays the mean ± SD using vertical bars.

Association Between BMI and Physiological Measures

Pearson correlation was used to explore the relationship between BMI and autonomic/cardiovascular variables. As presented in **Table 3**, BMI showed strong positive associations with heart rate, SBP, and DBP, and a strong inverse correlation with RMSSD ($r = –0.77$).

Figure 2. Mean ± SD Distribution of Key Variables Across Groups



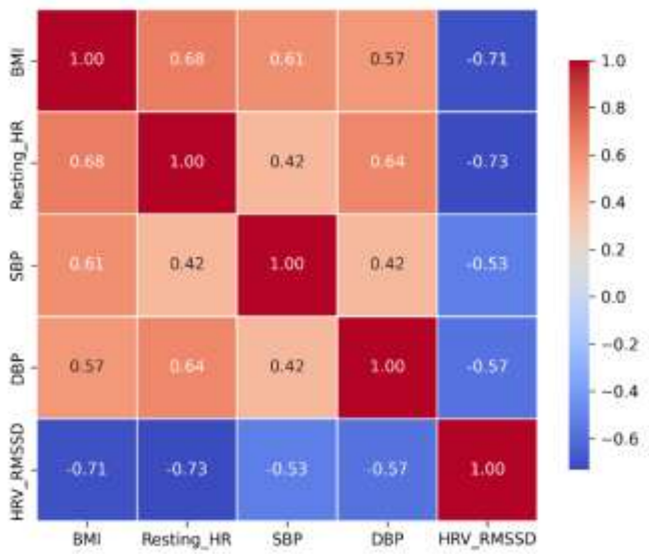
(Vertical bars show mean and standard deviation for each physiological measure. HRV reduction in obese participants is visibly prominent.)

Table 3. Pearson Correlation Between BMI and Physiological Parameters

Parameter	Pearson's r	p-Value
Resting HR	+0.71	<0.0001
SBP	+0.64	<0.0001
DBP	+0.68	<0.0001
RMSSD	–0.77	<0.0001

These associations are also visually represented in **Figure 3**, a correlation heatmap showing direction and strength. Notably, RMSSD displays the most pronounced inverse relationship with BMI.

Figure 3. Correlation Heatmap Between BMI and Cardiovascular Parameters



(Blue-to-red gradient indicates negative to positive correlation. RMSSD shows the strongest inverse association with BMI.)

Direction and Significance Summary

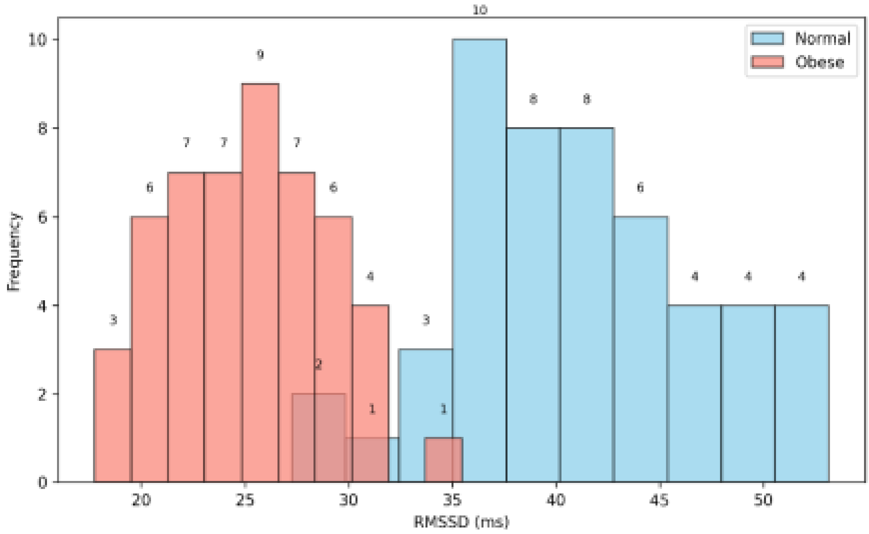
To synthesize these findings, **Table 4** presents the overall directionality of changes and statistical relevance. All differences were in the expected direction, indicating sympathetic predominance and vagal suppression in the obese group.

Table 4. Summary of Group Differences and Significance

Parameter	Trend in the Obese Group	Statistically Significant
Resting HR	Increased	Yes
SBP	Increased	Yes
DBP	Increased	Yes
RMSSD	Decreased	Yes
BMI	Increased	Yes

To further illustrate HRV distribution patterns, **Figure 4** presents overlaid histograms of RMSSD values in both groups. The leftward shift in the obese group confirms parasympathetic withdrawal.

Figure 4. Histogram of RMSSD Distribution in Normal vs. Obese Groups



(Frequency distribution shows reduced HRV in obese participants, highlighting autonomic dysregulation.)

Summary of Core Findings

- All obese participants exhibited significantly higher resting HR and BP ($p < 0.001$).
- RMSSD was markedly lower in the obese group, reflecting reduced vagal tone.
- BMI correlated strongly with autonomic markers, positively with sympathetic activity, and inversely with parasympathetic control.
- These changes suggest early subclinical autonomic dysregulation linked to adiposity.

DISCUSSION

This study demonstrates that obesity in young adults is associated with marked autonomic alterations, evidenced by elevated resting heart rate and blood pressure, alongside significantly reduced heart rate variability (RMSSD). These findings confirm that even in a population of otherwise healthy, first-year medical students, increased adiposity correlates with early signs of autonomic imbalance. The obese group exhibited significantly higher resting HR (83.87 bpm vs. 72.09 bpm), SBP (129.69 mmHg vs. 118.59 mmHg), and DBP (85.91 mmHg vs. 74.89 mmHg), with all p-values < 0.0001. RMSSD, a sensitive index of parasympathetic modulation, was substantially lower in obese participants (25.16 ms vs. 41.09 ms), suggesting suppressed vagal activity and sympathetic dominance. This pattern aligns with prior studies that link obesity with reduced HRV in Indian youth [8][9]. Increased resting HR observed among obese students may represent a compensatory autonomic response to increased metabolic demand and central adiposity. Elevated heart rate has been linked to higher cardiovascular morbidity in longitudinal studies, especially when exceeding 80–85 bpm at rest [10]. These patterns are not only indicative of autonomic stress but also modifiable through behavioral and lifestyle changes, particularly in younger populations. The inverse correlation between BMI and RMSSD (r = –0.77) observed in our cohort highlights the early decline in vagal tone associated with adiposity. Similar results were reported by Thayer et al., who demonstrated that lower RMSSD values independently predict impaired baroreflex sensitivity and early atherosclerotic changes [11]. Given that all participants were medically stable and free from known hypertension, these findings point toward subclinical, obesity-driven autonomic remodeling. Increased blood pressure readings among the obese group also warrant attention. While none of the participants had a prior diagnosis or treatment for hypertension, 7 out of 50 obese students recorded diastolic BP >100 mmHg. These findings echo reports by Banerjee et al., who noted elevated SBP and DBP in obese Indian medical students, despite the absence of overt disease [12]. The sympathetic overactivity observed here may reflect early neurovascular dysregulation, which, if left unchecked, may contribute to sustained hypertensive states later in life. Notably, HRV was evaluated using time-domain analysis (RMSSD), which, although reliable and easy to implement, does not provide frequency-specific insights. We did not assess low-frequency (LF), high-frequency (HF), or LF/HF ratio components, which could have further characterized sympathovagal shifts. Future studies should integrate frequency-domain metrics alongside baroreflex and biochemical markers for comprehensive autonomic profiling. Another limitation is the exclusion of central adiposity measures like the waist-hip ratio (WHR) or waist circumference. Recent research suggests these indices may better predict autonomic dysfunction than BMI alone [13]. For instance, Chandrasekaran et al. found that waist circumference, rather than BMI, had a stronger association with metabolic risk among Indian adolescents, a group physiologically close to our own [14]. Despite these limitations, the study's strengths lie in its strict participant homogeneity, standardized measurement protocols, and the use of validated digital tools for physiological assessment. All recordings were taken under uniform forenoon conditions to minimize diurnal variation in HR and BP, which often confound field-based measurements. The implications of these findings extend beyond clinical metrics. In the high-pressure environment of medical education, students often deprioritize health due to academic demands. The autonomic shifts identified here are not just biomarkers, they are early warning signs. They suggest a physiological cost to sedentary lifestyles and irregular routines, even in populations presumed to be "health-aware."Early interventions, such as aerobic exercise, stress management programs, and yoga-based vagal activation techniques, have shown promising results in restoring HRV and reducing sympathetic burden [15][16]. Medical institutions should consider embedding wellness modules that go beyond fitness camps, focusing instead on long-term behavioral change and biometric feedback.

CONCLUSION

Obesity in young adults is associated with elevated heart rate, increased blood pressure, and reduced vagal tone, as indicated by significantly lower RMSSD values. These autonomic shifts reflect early cardiovascular strain, even in medically stable individuals. Routine screening using HRV may help identify at-risk youth and prompt timely lifestyle interventions within academic settings.

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