



Association Between Body Mass Index and Blood Pressure Variability Among Young Adults: A Cross-Sectional Study

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ABSTRACT

Background: Rising body mass index (BMI) in young adults is linked to early blood pressure (BP) dysregulation. Short-term blood pressure variability (BPV), beyond mean BP, reflects autonomic and vascular instability.

Objectives: To assess the association between BMI and within-visit systolic and diastolic BP variability among young adults.

Methods: One hundred participants aged 18–25 years underwent anthropometry and seated BP recording. Three BP readings were obtained at 5-minute intervals; BPV was defined as the standard deviation of the three readings. Pearson correlation and multivariable linear regression (adjusted for age and sex) were applied.

Results: Mean age was 21.8 ± 2.4 years; 54% were male. Mean BMI was 23.9 ± 4.1 kg/m². Mean systolic/diastolic BP were 118.6 ± 11.8 and 76.4 ± 8.6 mmHg. Mean systolic/diastolic BPV were 7.2 ± 2.8 and 5.4 ± 2.1 mmHg. Systolic BPV rose from 5.8 ± 1.9 mmHg (underweight) to 9.4 ± 3.0 mmHg (obese), with a similar rise in diastolic BPV. BMI showed positive correlations with systolic BPV ($r = 0.52$) and diastolic BPV ($r = 0.47$). BMI remained an independent predictor of systolic BPV ($\beta = 0.38$) and diastolic BPV ($\beta = 0.34$).

Conclusion: Elevated BMI emerged as an independent determinant of increased within-visit BP variability among young adults.

Keywords: body mass index; blood pressure; blood pressure variability; young adults; obesity.

INTRODUCTION

Excess adiposity is no longer confined to midlife; it is increasingly observed in late adolescence and early adulthood, a period when cardiometabolic trajectories are often established. Higher body mass index (BMI) promotes blood pressure (BP) elevation through intertwined mechanisms that include sympathetic activation, impaired pressure natriuresis, activation of the renin-angiotensin-aldosterone system, and structural changes within the kidney and vasculature [1]. Population-level data in young adults demonstrate a graded relationship between BMI and both systolic and diastolic BP, indicating that risk amplification starts well before overt clinical disease [2]. Indian campus-based studies similarly report a substantial burden of elevated BP states among medical students and other young adults, with anthropometric indices showing clear links to prehypertension [3].

Accurate identification of early BP dysregulation requires standardized measurement. The American Heart Association scientific statement emphasizes appropriate cuff selection, a period of seated rest, and repeated readings to reduce measurement noise and improve classification [4]. For clinical and epidemiologic comparability, BP categories are commonly operationalized using established thresholds such as those proposed in the Joint National Committee report, which introduced the prehypertension category and highlighted its prognostic relevance [5]. More recent American guidelines have lowered diagnostic thresholds for hypertension, underscoring a growing emphasis on earlier detection and prevention in younger age groups [6].

Beyond mean BP levels, blood pressure variability (BPV) has emerged as a complementary marker of cardiovascular risk. Short-term fluctuations reflect dynamic interactions between autonomic tone, arterial compliance, baroreflex function, and behavioral factors. A comprehensive review has outlined the clinical importance of BPV and practical approaches for its assessment across time scales [7]. Mechanistic work further indicates that heightened variability can contribute to target-organ stress, partly through intermittent exposure to higher pressures and enhanced sympathetic drive [8]. Within-visit BPV, derived from repeated office readings taken during the same encounter, has been associated with an adverse cardiovascular risk profile in large observational datasets [9]. Longer-term variability also carries prognostic information; visit-to-visit variability and episodic hypertension have been linked to higher stroke risk independent of mean BP [10], and meta-analyses confirm associations with cardiovascular outcomes and mortality [11,12]. Ambulatory BP variability likewise shows long-term prognostic value in general population cohorts [13]. Importantly, obesity in youth has been associated not only with higher BP levels but also with higher BP variability on ambulatory monitoring, suggesting that adiposity-related hemodynamic instability begins early [14].

Despite this growing evidence based data on the relationship between BMI and within-visit BPV in Indian young adults remain limited. Establishing this association in a physiology-based setting can inform screening strategies that move beyond single BP values and incorporate repeated measurements. Therefore, the objectives of this study were to determine the distribution of BMI categories and BP status among young adults and to evaluate the association between BMI and within-visit systolic and diastolic BP variability.

MATERIAL AND METHODS

Study design and setting: A cross-sectional study was undertaken in the Department of Physiology, Mamata Medical College, Khammam, Telangana, India, over six months (March 2025 to August 2025).

Participants and sample size: One hundred young adults aged 18–25 years were enrolled after informed consent. Participants were recruited from the college campus and surrounding community by consecutive sampling during the study period. Individuals with a history of physician-diagnosed hypertension, diabetes mellitus, chronic kidney disease, cardiovascular disease, acute febrile illness, or current use of medications known to influence BP (including antihypertensives, systemic corticosteroids, and sympathomimetics) were excluded. Pregnant participants were not enrolled.

Anthropometry and BMI classification: Height was recorded to the nearest 0.1 cm using a stadiometer and weight to the nearest 0.1 kg using a calibrated digital scale, with participants in light clothing and without footwear. BMI was calculated as weight (kg) divided by height squared (m²). BMI categories were defined using World Health Organization cut-offs: underweight (<18.5 kg/m²), normal (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥30.0 kg/m²).

Blood pressure measurement and BP classification: Office BP was measured using a validated automated oscillometric device with an appropriately sized cuff. The protocol followed recommendations for standardized BP measurement, including avoidance of caffeine and vigorous activity for at least 30 minutes, seated rest for 5 minutes, back supported, feet flat on the floor, and the arm supported at heart level [4]. Three BP readings were obtained at five-minute intervals; the mean of the three readings was used for the descriptive BP profile. BP status was categorized using Joint National Committee thresholds: normotension, prehypertension (SBP 120–139 mmHg and/or DBP 80–89 mmHg), and stage 1 hypertension (SBP 140–159 mmHg and/or DBP 90–99 mmHg) [5]. Contemporary guideline thresholds were considered during interpretation to maintain clinical relevance [6].

Definition of blood pressure variability: Within-visit BPV was quantified separately for systolic and diastolic BP as the standard deviation (SD) of the three consecutive readings obtained during the same visit, a pragmatic approach aligned with clinical BPV assessment frameworks [7].

Statistical analysis: Data were entered into a password-protected database and analyzed using standard statistical software. Continuous variables are presented as mean ± SD, and categorical variables as frequency and percentage. Differences in BPV across BMI categories were assessed using one-way analysis of variance. Pearson correlation coefficients were computed to evaluate linear associations between BMI and BP/BPV parameters. Multivariable linear regression models were constructed with systolic BPV and diastolic BPV as dependent variables, adjusting for age and sex. A two-sided p-value <0.05 was considered statistically significant.

Ethical considerations: The study protocol was approved by the Institutional Ethics Committee of Mamata Medical College. Participation was voluntary, confidentiality was maintained, and all procedures complied with principles for biomedical research involving human participants.

RESULTS

A total of 100 young adults were analyzed. The mean age was 21.8 ± 2.4 years (range: 18–25 years), and males constituted 54% of the cohort. The overall mean BMI was 23.9 ± 4.1 kg/m². Mean systolic and diastolic BP were 118.6 ± 11.8 mmHg and 76.4 ± 8.6 mmHg, respectively (Table 1).

Table 1. Baseline Characteristics of Study Participants (N = 100)

Variable	Value
Age (years), Mean \pm SD	21.8 ± 2.4
Age range (years)	18–25
Gender, n (%)	
Male	54 (54%)
Female	46 (46%)
BMI (kg/m ²), Mean \pm SD	23.9 ± 4.1
Systolic BP (mmHg), Mean \pm SD	118.6 ± 11.8
Diastolic BP (mmHg), Mean \pm SD	76.4 ± 8.6

Using WHO BMI cut-offs, 18% of participants were underweight, 42% had normal BMI, 26% were overweight, and 14% were obese. With respect to BP status, 67% were normotensive, 24% had prehypertension, and 9% met criteria for stage 1 hypertension (Table 2).

Table 2. Distribution of BMI Categories and Blood Pressure Classification

Parameter	Category	n (%)
BMI Classification	Underweight (<18.5)	18 (18%)
BMI Classification	Normal (18.5–24.9)	42 (42%)
BMI Classification	Overweight (25–29.9)	26 (26%)
BMI Classification	Obese (≥ 30)	14 (14%)
Blood Pressure Status	Normotensive	67 (67%)
Blood Pressure Status	Prehypertension	24 (24%)
Blood Pressure Status	Stage 1 Hypertension	9 (9%)

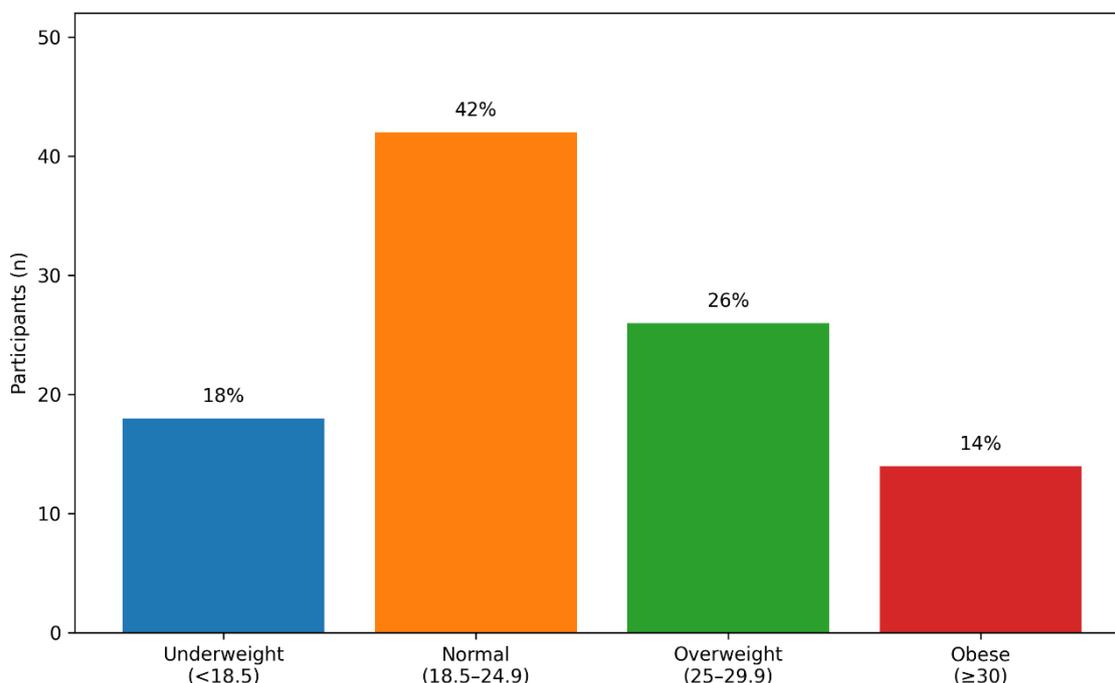


Figure 1: Distribution of BMI Categories

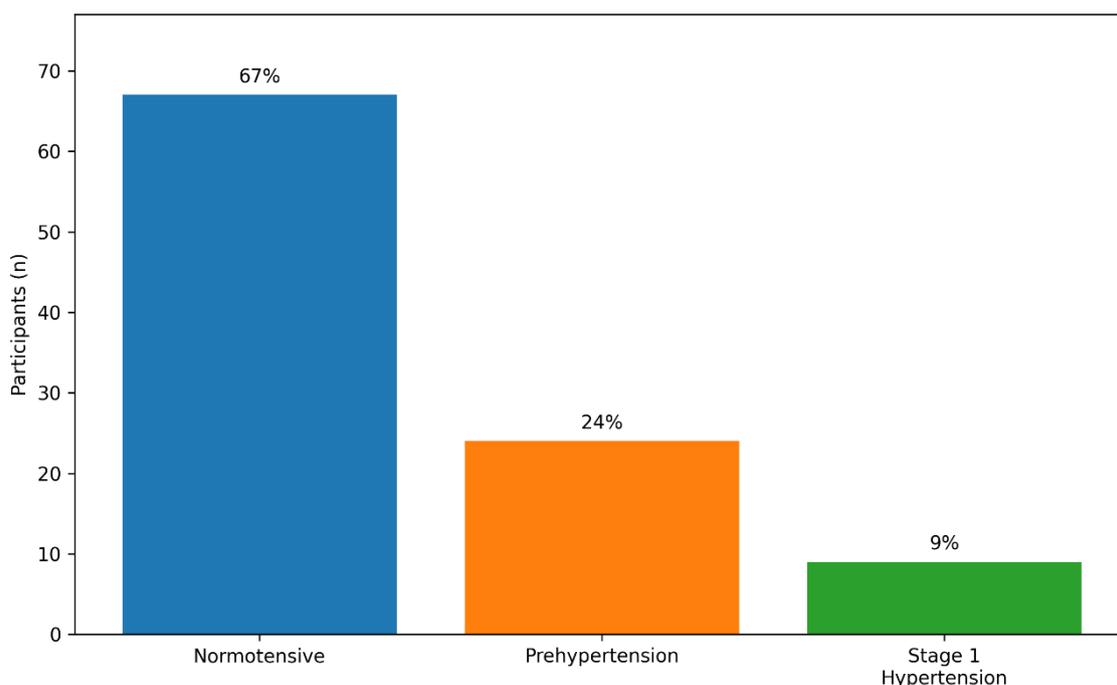


Figure 2: Blood Pressure Classification

Within-visit BPV, expressed as the SD of three consecutive readings, showed mean systolic BPV of 7.2 ± 2.8 mmHg and mean diastolic BPV of 5.4 ± 2.1 mmHg. When stratified by BMI, systolic BPV increased progressively from underweight to obese categories (5.8 ± 1.9 to 9.4 ± 3.0 mmHg). A parallel graded rise was observed for diastolic BPV. Differences in both systolic and diastolic BPV across BMI categories were statistically significant ($p < 0.001$) (Table 3).

Table 3. Blood Pressure Variability According to BMI Categories

BMI Category	Systolic BPV (mmHg) Mean \pm SD	Diastolic BPV (mmHg) Mean \pm SD
Underweight	5.8 ± 1.9	4.2 ± 1.5
Normal	6.5 ± 2.3	4.9 ± 1.8
Overweight	8.1 ± 2.7	6.0 ± 2.2
Obese	9.4 ± 3.0	7.1 ± 2.4
p-value	<0.001	<0.001

Correlation analysis demonstrated moderate positive relationships between BMI and systolic BPV ($r = 0.52$, $p < 0.001$) and between BMI and diastolic BPV ($r = 0.47$, $p < 0.001$). BMI also correlated positively with mean SBP ($r = 0.49$, $p < 0.001$) and mean DBP ($r = 0.44$, $p < 0.001$). On multivariable regression adjusted for age and sex, BMI remained an independent predictor of systolic BPV ($\beta = 0.38$, $p < 0.001$) and diastolic BPV ($\beta = 0.34$, $p = 0.002$). Each 1 kg/m^2 increase in BMI corresponded to an approximate 0.32 mmHg increase in systolic BPV (Table 4).

Table 4. Correlation and Regression Analysis Between BMI and Blood Pressure Parameters

Variable	Correlation (r)	p-value	Standardized β	p-value
BMI vs Systolic BPV	0.52	<0.001	0.38	<0.001
BMI vs Diastolic BPV	0.47	<0.001	0.34	0.002
BMI vs Mean SBP	0.49	<0.001	—	—
BMI vs Mean DBP	0.44	<0.001	—	—

DISCUSSION

In this cross-sectional cohort of young adults, higher BMI was consistently associated with greater within-visit systolic and diastolic BP variability, alongside higher mean BP. The observed graded increase in BPV across BMI categories suggests that adiposity-related hemodynamic instability is detectable even in early adulthood, when absolute BP values often remain within the normotensive range.

Several biological pathways plausibly link increasing BMI to higher BPV. Obesity is characterized by heightened sympathetic activity, altered renal sodium handling, and activation of neurohumoral systems that collectively increase vascular tone and pressure responsiveness [10]. Variability is further influenced by baroreflex buffering and arterial compliance; mechanistic perspectives emphasize that intermittent BP surges can amplify vascular stress and contribute to target-organ injury beyond the effect of mean BP alone [8]. Reviews of BPV assessment highlight that variability across short and long time scales captures distinct physiology and carries independent clinical information [7]. In our study, within-visit BPV (derived from three standardized readings) likely reflects a combination of autonomic lability, situational reactivity, and early vascular changes.

The current findings align with prior work linking BPV to adverse risk profiles and outcomes. Within-visit BPV has been associated with poor BP control and a clustering of cardiometabolic risk factors in large multicenter data [9]. Longitudinal evidence further supports the prognostic importance of variability: visit-to-visit variability and episodic hypertension predict stroke risk independent of mean systolic pressure [10], and meta-analyses confirm associations between variability and cardiovascular events as well as all-cause mortality [11,12]. Ambulatory variability has also shown long-term prognostic value in general populations [13]. Importantly, evidence from youth indicates that obesity is associated with higher ambulatory BP levels and larger discrepancies between office and ambulatory measurements, consistent with early instability in BP regulation [14]. Taken together, these data support the interpretation that BPV can act as an early signal of cardiometabolic risk in young adults with higher BMI.

From a public health perspective, the proportion of participants with prehypertension underscores the need for early screening and counseling, echoing observations from Indian medical student populations where elevated BP states are common and track with anthropometric indices [13]. Because BPV estimates depend on measurement quality, the standardized multi-reading protocol recommended by the American Heart Association strengthens the reliability of within-visit variability assessment [14]. Use of established BP thresholds, including those defining prehypertension, facilitates comparison with earlier literature, while contemporary guideline updates highlight the importance of risk-based prevention even at lower BP levels.

Limitations

This single-center study used a cross-sectional design, which prevents causal inference between BMI and BP variability. The sample was limited to 18–25-year-old and was recruited by consecutive sampling, reducing population representativeness. BP was recorded on a single visit, and day-to-day variability or white-coat effects were not quantified with home or ambulatory monitoring. Residual confounding from diet, physical activity, sleep, and stress was not fully captured.

CONCLUSION

In this cohort of 100 young adults, increasing BMI was associated with higher mean BP and, importantly, greater within-visit BP variability. Systolic BPV rose steadily from the underweight to obese categories, and BMI showed moderate positive correlations with both systolic and diastolic BPV. After adjustment for age and sex, BMI remained an independent predictor of BP variability, indicating that adiposity contributes to early hemodynamic instability even before sustained hypertension becomes common. BPV can therefore serve as an additional, feasible clinical signal of early vascular-autonomic dysregulation. These findings support incorporating repeated BP measurements and variability metrics into young adult screening, alongside routine anthropometry, to guide targeted preventive counselling and follow-up planning.

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