



Ambulatory blood pressure patterns and associated lifestyle behaviours in a cross-sectional study of young adult university students.

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Abstract

Background:

Hypertension (HTN) is a significant silent health threat in all age groups, including young adults, often presenting no symptoms while causing long-term cardiovascular damage. This study aimed to explore ambulatory blood pressure (ABP) patterns, nocturnal BP changes, BP variability, morning BP surges, and the association between ABP and lifestyle factors in healthy university students.

Methods:

Demography, lifestyle, and family history of HTN were obtained using a questionnaire. ABP was measured using a portable automatic oscillometric monitor. Study participants were recruited from students enrolled at the University of Bamenda, Cameroon, who had no known history of cardiovascular disease and voluntarily agreed to collaborate. Data were analyzed using SPSS®, and the relationship between ABP parameters.

Results:

A total of 105 individuals participated in this study, and their mean age was 23.08±4.78. With a few exceptions, the mean BPs of males were slightly higher than those of females, with elevated 24HSBP of males significantly ($p<0.02$) higher than that of females and normal 24HDBP of males significantly ($p<0.03$) higher than that of females. The pulse rate of females at 60-100 bpm was significantly higher than that of males in the daytime ($p<0.009$) and at 24H ($p<0.003$). Most participants were non-dippers, with a mean SBP change of 5.12.7 mmHg and a mean DBP change of 5.49±2.6 mmHg. Morning surge in SBP was within 10-30 mmHg in 76 participants. Ambulatory BP was associated with salty food (> 5 g salt/day), sugar-sweetened beverages, insufficient sleep, and family history of HTN.

Conclusion:

Ambulatory BP monitoring is critical in detecting a comprehensive profile of BP patterns, and if used in combination with lifestyle patterns, will be crucial for tracking BP changes and, by extension, cardiovascular health in young adults.

Recommendation:

Thus, there's a need for widespread ABP monitoring of healthy youngsters in order to prevent future cardiovascular disease.

Keywords: Ambulatory blood pressure, Blood pressure variability, Lifestyle, Morning surge in blood pressure, Nocturnal blood pressure changes.

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Background

Hypertension (HTN) is a global public health crisis that occurs across all age groups, including young adults (18-24 years), middle-aged people (25-44 years), and older adults

(Meher et al., 2023; WHO, 2023). High BP in young people tracks with significantly elevated BP and HTN later in life and is associated with adverse cardiovascular outcomes (Hinton et al., 2020). Most (2/3) adults with HTN live in



low- and middle-income countries (LMIC) with an estimated prevalence of 30.8% - 48% women and 34% men, with very low levels of control (WHO, 2023);(Bayaraa et al., 2025);(Khan & Nadar, 2025). In fact, the African Region has the highest prevalence (27%) of HTN (WHO, 2023). The risk factors responsible for this high incidence of HTN are either non-modifiable or modifiable. Non-modifiable risk factors are those influenced by personal characteristics such as age, family history of HTN, gender, and genetic makeup. Modifiable risk factors include those that are influenced by lifestyle, such as excessive salt intake, low dietary potassium, smoking, low level of physical activity, being overweight and obese, excessive alcohol consumption, socioeconomic status, psychosocial stressors, and diabetes (Pilakkadavath & Shaffi, 2016; Sobierajski et al., 2022). The rising prevalence of HTN in LMICs is associated with lifestyle changes; thus, identifying and understanding these risk factors is critical for developing targeted prevention and management strategies (Sood et al., 2024).

Office BP, though useful, generally provides limited information on the real BP load and variability over the 24 h period (Angeli et al., 2023). Self-measured home BP has an advantage over office BP in that it allows BP monitoring for longer periods, is relatively less expensive, and is more widely available. Neither office BP nor home BP matches ambulatory blood pressure monitoring (ABPM), which is the gold standard for assessing blood pressure status. ABPMs can automatically measure and store multiple BP readings throughout the day and night and are therefore very useful for assessing BP during sleep (Lewandowska et al., 2023). ABPM is a noninvasive, fully automated technique in which BP is recorded over an extended period, typically 24 hours. A key advantage of ABPM over other methods is its ability to identify BP patterns, such as sustained, white-coat, masked, and nocturnal HTN, that cannot be detected with office BP alone (Niiranen et al., 2014). Many individuals without high daytime BP have high nighttime BP, which is itself associated with increased cardiovascular diseases (CVD) and mortality risk (Muntner et al., 2019). Patients with white coat HTN have similar cardiovascular risk profiles compared to patients with normotension, and most experts agree that these patients do not need medications. Masked HTN, which is estimated to be present in some adults without a HTN diagnosis, has at least twice the risk of cardiovascular events as those with normotension. Nocturnal HTN independently contributes to cardiovascular risk (Kronish et al., 2020). In addition, ABP monitoring provides access to blood pressure dipping and non-dipping status, early-morning surge patterns, pressure

loads, and pulse pressure variability. Among these, mean arterial pressure (MAP) is a crucial indicator of the circulating pressure load during a cardiac cycle (Karahan & Zor, 2024). There is accumulating evidence demonstrating the prognostic value of ABPM (Kim, 2010). The independent association between ambulatory BP, hypertensive target organ damage, and the risk of cardiovascular events in hypertensive patients (either treated or untreated) is now well established (Angeli et al., 2023). ABPM has a higher reproducibility and better correlation with end-organ damage than office blood pressure. Therefore, ABPM provides a more accurate assessment of blood pressure in a study subject (Yalçin et al., 2022). The superiority of 24-ABPM over office and home BP in predicting mortality is probably related to many factors, such as its ability to measure BP during sleep, its ability to diagnose subjects with white coat HTN, and masked HTN (Madin & Iqbal, 2006). This study evaluated the ambulatory blood pressure patterns, nocturnal BP changes, BP variability, morning BP surges, and the association between ABP and lifestyle factors in order to identify possible risk factors for hypertension in this healthy student population.

Materials and Methods

Study design and study setting

This was a cross-sectional study conducted at the University of Bamenda, in the North West Region of Cameroon, West-Central Africa. The study participants included healthy young students. The study was conducted from February 2024 to July 2024.

Research population

One hundred and five (105) students participated in this study. Participants were recruited from various departments of the University of Bamenda by a random sampling method. Participants could withdraw at any time. To mitigate bias, participants were selected by random sampling, standardized questionnaires were used for data collection, and data were analyzed by an independent biostatistician who was not involved in the collection or supervision process. The sample size of 100 was extrapolated from a sample size table (Ajay & Micah, 2014). Over 150 students were recruited to participate in the study. A thorough one-on-one explanation of the study requirements was given to each prospective participant, and 108 individuals signed consent forms.



Inclusion criteria

1. Students who voluntarily consented to participate in the study.
2. Students without a known history of hypertension or cardiovascular diseases.

Exclusion criteria

1. Students diagnosed with hypertension or being treated for hypertension using antihypertensive medications.

Ethical consideration

This study was conducted following approval from the Scientific Research Ethics Committee of the Faculty of Health Sciences, University of Bamenda, which adheres to the Declaration of Helsinki and was approved by the local Bioethics Committee.

Informed consent

All participants signed an informed consent form, and all consenting students who were not suffering from any debilitating condition were included in the study.

Questionnaire

All participants filled out a structured questionnaire, consisting of twenty-two (22) questions. The questions covered lifestyle risk factors (like salt intake, alcohol consumption, smoking, sedentary lifestyle) and family history of HTN. Demographic data (sex and age) were also collected.

Ambulatory blood pressure monitoring

After completing the questionnaire, participants were fitted with the CONTEC ABPM50 monitors (Qinhuangdao, China) and instructed about their behaviour during the study before the start of measurements; they were instructed to continue their daily routine, excluding vigorous exercise. The arm cuff was positioned on the non-dominant upper limb. Measurements were performed oscillometrically.

ABPM devices were set to automatically record daytime BP every 30 min and nighttime BP every hour. Daytime measurements were from 0600 to 2200, and nighttime BP readings every hour from 2200 to 0600 (Chase et al., 1997).

Statistical analysis

Data were analyzed using IBM SPSS® Statistics software. Results are presented as mean \pm SD. Demographic and lifestyle patterns were summarized using descriptive statistics (frequency (%)). Differences between groups were compared by Student's t-test, and the relationship between ABP parameters and lifestyle was assessed by chi-square test. The significance level for all analyses was set at $P < 0.05$.

Measurements of SBP, DBP, MAP, and PR were presented as mean \pm SD for the day, night, and full 24 h period.

BP variability, dipping status, and morning surge in BP were calculated using the formulae:

BP variability (coefficient of variation) = $(SD/av\ BP) * 100$

Dipping status (nocturnal BP fall) = $(Daytime\ BP - Nighttime\ BP/Daytime\ BP) * 100$

Morning surge in BP = average BP 2 H after awakening – lowest nighttime BP (Okada et al., 2013).

Where: SD – standard deviation; av – average

Results

Participant's characteristics

The characteristics of the participants are shown in Table 1. Out of the over 150 prospective participants, 108 accepted to participate in the study. Out of the 108 participants, 1 participant had incomplete ABP data, while 2 of them submitted partially filled questionnaires. Therefore, a total of 105 students participated in this study – 52 males and 53 females. The mean (\pm SD) age of the participants was 23.10 ± 4.73 ; that of the females was 21.8 ± 2.6 , and that of males was 24.37 ± 5.9 . A majority (79) of the participants were ≥ 21 years old.

Table 1: Baseline characteristics of participants

Demography	Females	Males
Mean age in years (SD)	21.80 \pm 2.6	24.37 \pm 5.9
In 20 years	16	10
In 21 years	37	42
Total n (%)	53 (50.48)	52 (49.52)



Lifestyle patterns of participants

The results of lifestyle patterns of participants expressed as n (%) are shown in Table 2. Feeding patterns were similar in both sexes, with more males (92.31%) perceiving their weight as normal, while more females (32.69%) than males (7.69%) reported a desire to lose weight. 30.19% of females and 46.15% of males had less than 8 hours of sleep per night. Few participants (5.77% females; 13.46% males) reported

consuming alcohol. Only 1.92% of participants reported being active smokers, while 26.92% of females and 15.38% of males reported being passive smokers. 34.62% of females and 19.23% of males were sedentary, while 59.62% of females and 46.15% of males exercised 30 mins-3 hrs per week. Over 80% of participants reported walking for at least 30 mins a day, with substantial periods of relaxation. Family history of hypertension was reported in 63.4% females and 38.46% males who participated in the study

Table 2: Lifestyle patterns of participants

Lifestyle	Females	Males
Feeding patterns		
- Consumption of regular meals	38 (73.08)	37 (71.15)
- Consumption of more than 5 g of salt per day	10 (19.23)	15 (28.85)
- Consumption of sugary and fatty foods	26 (50)	17 (32.69)
- Binge eating	13 (25)	12 (23.08)
- Perception of weight:		
• Feeling of healthy weight	35 (67.31)	48 (92.31)
• Want to lose weight	17 (32.69)	4 (7.69)
- Consumption of fruits and vegetables per week:		
• 1 time	22 (42.31)	19 (36.54)
• 2 times	18 (34.62)	9 (17.31)
• 3 times	7 (13.46)	13 (25)
• 4 times	5 (9.62)	10 (19.23)
Sufficient sleep per night	36 (69.23)	28 (53.85)
- Sleep hrs for insufficient sleep:		
• 3 hrs	0	1 (1.92)
• 4 hrs	6 (11.54)	7 (13.46)
• 5 hrs	6 (11.54)	13 (25)
• 6 hrs	4 (7.69)	3 (5.77)
Active smokers	1 (1.92)	0
Passive smokers	14 (26.92)	8 (15.38)
Alcohol intake in litres/week		
- None	49 (94.23)	45 (86.54)
- 0.5-3 L	3 (5.77)	7 (13.46)
Sugar-sweetened beverages in litres per week		
- None	2 (3.85)	3 (5.77)
- 0.5-7 L	50 (96.15)	49 (94.23)
- Need to drink (alcohol or beverage) to get going	9 (17.31)	4 (7.69)
Regular exercise	22 (42.31)	29 (55.77)
- Number of exercise hours/week:		
• None	18 (34.62)	10 (19.23)
• 30 mins – 3 hrs	31 (59.62)	24 (46.15)
• 4 -7 hrs	1 (1.92)	13 (25)
• 8 hrs and above	2 (3.85)	5 (9.62)
- At least 30 mins of continuous walking		



Relaxation	45 (86.54)	46 (88.46)
- Duration of relaxation		
• 30 mins – 1 hr	21 (40.38)	26 (50)
• 2 - 3 hrs	22 (42.31)	20 (38.46)
• 4 – 6 hrs	6 (11.54)	2 (3.85)
Family history of HTN	33 (63.46)	20 (38.46)

Results are expressed as n (%); HTN- hypertension.

Daytime, nighttime, and 24-hour ambulatory blood pressure of participants

The mean \pm SD of daytime, nighttime, and 24H ambulatory SBP and DBP of participants are recorded in Table 3. The results of the various participants are presented in distinct BP categories. With a few exceptions, the mean BPs of males were slightly higher than those of females in most categories, with the 24HSBP within the range of 120-129

mmHg of males significantly ($p < 0.02$) higher than that of females, and 24HDBP < 80 mmHg of males significantly ($p < 0.03$) higher than that of females. In the daytime, nighttime, and 24-hour SBP ≥ 130 mmHg categories, there were 28, 5, and 5 participants, respectively. Of the 38 participants in this category, 22 were male. Meanwhile, participants who had daytime DBP ≥ 85 mmHg, nighttime DBP > 90 , or 24-hour DBP ≥ 90 were 9, 2, and 2, respectively, and 8 of the 13 were males.

Table 3: Daytime, nighttime, and 24-hour ambulatory blood pressure of participants

ABP Parameters	Category	Females (n)	Males (n)	P value
DTSBP (mmHg)	<120	114.48 \pm 5.1 (17)	111.79 \pm 6.8 (14)	0.82
	120-129	122.38 \pm 2.7 (22)	124.90 \pm 2.9 (24)	0.35
	130-134	132.96 \pm 1.6 (7)	132.42 \pm 2.02 (9)	0.68
	≥ 135	136.59 \pm 1.2 (7)	140.18 \pm 3.4 (5)	0.06
DTDBP (mmHg)	<60	/	56.69 \pm 3.6 (4)	
	60-79	72.34 \pm 6.2 (36)	71.75 \pm 4.9 (28)	0.87
	80-84	82.47 \pm 1.5 (14)	83.26 \pm 0.8 (14)	0.15
	≥ 85	87.75 \pm 3.9 (3)	89.67 \pm 3.5 (6)	0.74
NTSBP (mmHg)	<120	107.44 \pm 7.3 (32)	109.16 \pm 6.2 (30)	0.27
	120-129	123.63 \pm (19)	123.35 \pm 2. (19)	0.72
	130-139	131 (1)	134.56 \pm 3.7 (4)	
NTDBP (mmHg)	50 -69	62.29 \pm 6.1 (33)	63.15 \pm 5.2 (28)	0.62
	70-79	76.09 \pm 2.5 (11)	76.49 \pm 2.7 (17)	0.87



	80-90	82.95±1.5 (8)	82.74±2.38 (6)	0.98
	≥90	91.13 (1)	91.43 (1)	/
24HSBP (mmHg)	<120	107.44±7.3 (32)	109.16±6.2 (30)	0.27
	120-129	123.63±2.2 (19)	123.35±2.2 19	0.72
	130-139	131 (1)	134.56±3.7 (4)	/
24HDBP (mmHg)	50-69	62.29±6.1 (33)	63.15±5.2 (28)	0.62
	70-79	76.09±2.5 (11)	76.49 (17)	0.87
	80-89	82.96±1.5 (8)	82.74 (6)	0.98
	≥ 90	91.13 (1)	91.43 (1)	/

Results are expressed as mean ± SD; 24HDBP- 24 hours diastolic blood pressure; 24HSBP- 24 hours systolic blood pressure; bpm- beats per minute; DTDBP- daytime diastolic blood pressure; DTSBP- daytime systolic blood pressure; NTDBP- nighttime diastolic blood pressure; NTSBP- nighttime systolic blood pressure.

Daytime, nighttime, and 24-hour mean arterial pressure and pulse rate of participants

The mean ± SD of daytime, nighttime, and 24-h ambulatory MAP and PR of participants are recorded in Table 4. The MAP and PR are categorized. During the day, a majority of participants (37 females; 38 males) had MAP < 90 mmHg; at night, 52 participants (29 females; 23 males) had MAP < 80 mmHg; and for 24H, 52 participants (29 females; 23 males) had MAP < 80 mmHg. A majority of participants had a pulse rate between 60 and 100 bpm during the day (51 females; 49 males), at night (46 females; 43 males), and 24 hours (46 females; 43 males). The pulse rate of females at 60-100 bpm was significantly higher than that of males in the daytime (p<0.009) and at 24H (p<0.003) recordings.

Table 4: Daytime, nighttime, and 24-hour MAP and PR of participants

ABP parameter	Category	Females (n)	Males (n)	P value
DTMAP (mmHg)	<94	82.92±6.8 (37)	84.07±8.5 (38)	0.55
	94-95	95.01±0.9 (11)	94.88±0.5 (8)	0.79
	96-103	98.56±3.3 (4)	100.03±2.4 (5)	0.51
	≥104	/	108±0.2 (2)	
DTPR (bpm)	<60	/	54.75±2.8 (2)	
	60-100	79.22±7.4 (51)	75.26±7.5 (49)	0.009
	>100	101.19±1.0 (2)	101.5 (1)	
NTMAP (mmHg)	<80	72.42±5.9 (29)	73.48±5.4 (23)	0.56
	80-81	81.55±0.26 (5)	80.38 (1)	
	82-87	85.54±2.08 (5)	84.78±1.8 (15)	0.55
	>88	92.34±3.7 (15)	92.89±4.01 (12)	0.89
NTPR (bpm)	<60	56.64±2.04 (6)	57±1.8 (6)	0.65
	60-100	74.26±6.7 (46)	72.54±8.8 (43)	0.31



	>100	102.14 (1)	102.21±3.3 (3)	/
24HMAP (mmHg)	<80	72.42±6.0 (29)	73.48±5.4 (23)	0.56
	80-87	83.54±2.5 (10)	84.51±2.1 (16)	0.27
	≥88	92.34±3.7 (15)	92.89±4.0 (12)	0.89
24HTPR (bpm)	<60	56.64±2.0 (6)	57±1.8 (6)	0.65
	60-100	74.26±6.7 (46)	72.54±8.8 (43)	0.31
	>100	102.14 (1)	102.21±3.3 (3)	

Results are expressed as mean ± SD; 24HMAP- 24 hours mean arterial blood pressure; 24HPR- 24 hours pulse rate; bpm- beats per minute; DTMAP- daytime mean arterial pressure; NTMAP- nighttime mean arterial pressure; DTPR- daytime pulse rate; NTPR- nighttime pulse rate

Blood pressure variability of participants

There was no significant difference in BP variability between males and females, but daytime and 24 hr SBP variability were slightly higher in males than in females, and daytime, nighttime, and 24 hr DBP variability were also slightly higher in males than in females (Table 5).

Table 5: Blood pressure variability

	Females	Males	p-value
SBP variability			
DT	3.70±1.71	4.01±1.53	0.27
NT	5.88±2.57	5.75±2.01	0.87
24H	11.69±3.32	12.60±4.51	0.22
DBP variability			
DT	7.75±4.07	8.87±4.63	0.29
NT	10.26±5.07	10.52±4.33	0.76
24H	18.26±5.28	20.20±7.27	0.14

Results are expressed as mean ± SD; DBP- diastolic blood pressure; DT- daytime; NT- nighttime; SBP- systolic blood pressure.

Nocturnal change in blood pressure of participants

The mean ± SD of participants is shown in Table 6. The number of non-dippers (SBPΔ; n = 55, DBPΔ; n = 37) was more than the number of dippers (SBPΔ; n = 28, DBPΔ; n =

33). There was no significant difference in nocturnal BP status between males and females. Extreme dippers represented the smallest group of participants (SBPΔ; n = 5, DBPΔ; n = 12) in this study.

Table 6: Nocturnal change in blood pressure

Nocturnal BP status	Females (n)	Males (n)	p-value
Dippers			
% SBPΔ	13.52 ±2.68 (16)	15.15±3.02 (12)	0.26
% DBPΔ	15.61±2.51	14.72±3.2	0.5



	(13)	(20)	
Extreme dippers			
% SBPΔ	24.55±2.71 (4)	21.03 (1)	/
% DBPΔ	28.60±5.63 (9)	25.07±0.65 (3)	0.27
Non dippers			
% SBPΔ	5.37±2.83 (25)	4.87±2.57 (30)	0.51
% DBPΔ	4.95±2.69 (18)	6.01±2.5 (19)	0.27
Risers			
% SBPΔ	-3.68±2.49 (9)	-5.99±5.8 (8)	0.51
% DBPΔ	-8.36±7.67 (13)	-10.91±8.26 (10)	0.58

Results are expressed as mean ± SD; %DBPΔ- percentage change in diastolic blood pressure; %SBPΔ- percentage change in systolic blood pressure.

Morning surge in blood pressure of participants

Morning surge in BP is represented as mean ± SD in Table 7. Only one female participant had an SBP surge >30 mmHg, while 10 participants (3 females and 7 males) had a DBP surge >23.

Table 7: Morning surge in blood pressure

Parameter	Category	Females (n)	Males (n)	P value
SBP surge (mmHg)	≤10-30	12.66±9.51 (37)	11.37±7.99 (39)	0.39
	>30	44.75 (1)	/	
DBP surge (mmHg)	≤7-23	9.44±5.66 (32)	10.47±6.7.25 (31)	0.65
	>23	26.97±2.24 (3)	27.04±1.75 (7)	

Results are expressed as mean ± SD; DBP- diastolic blood pressure; SBP- systolic blood pressure.

Association between ambulatory blood pressure and lifestyle patterns

Daytime, nighttime, and 24 H SBP and DBP were significantly associated with various lifestyle patterns (Table 7). Some of the participants who reported that they consume lots of salty food or eat lots of sugary/fatty food or often have the urge to eat or observe 3-6 hours sleep per night or drink sugar-sweetened beverages weekly or passive

smoking or had a family history of hypertension had normal BPs, while others had elevated BPs. This trend was not different among those who indicated that they consume regular meals, eat fruits/vegetables weekly, feel they have a healthy weight, get sufficient sleep, exercise regularly, and take time to relax. Those who reported that they smoked or consumed alcohol were very few. Only significant data is shown in Table 7.



Table 7: Association between ABP and lifestyle

Lifestyle	BP	Females				P value	Males				P value	Cohort				P value
		<120	120-129	130-134	≥135		<120	120-129	130-134	≥135		<120	120-129	130-134	≥135	
	DT SB P	<120	120-129	130-134	≥135		<120	120-129	130-134	≥135		<120	120-129	130-134	≥135	
ERM		12	15	5	6		13	16	6	1	0.05	25	31	11	7	
LSF		5	3	1	1		8	3	2	2	0.023	13	6	3	3	0.039
GSS		15	17	5	4		10	13	5	0		25	30	10	4	0.033
3-6HS/N		17	21	6	8		13	24	9	4		30	45	15	12	0.054
	DT DB P	<60	60-79	80-84	≥85		<60	60-79	80-84	≥85		<60	60-79	80-84	≥85	
LSF			10	0	0	0.038	3	7	2	3		3	17	2	3	0.011
GSS			28	10	3		4	15	9	0	0.011	4	43	19	3	
3-6HS/N			34	15	3		3	27	14	6	0.020	3	61	29	9	0.001
SSB			34	15	3		4	27	14	6	0.017	4	61	29	9	
30MW			28	14	3		3	27	14	5	0.030	3	55	28	8	
	NT SB P	<120	120-129	130-139			<120	120-129	130-139			<120	120-129	130-139		
ERM		21	16	1			23	12	1		0.043	44	28	2		
LSF		7	2	1			13	2	0		0.012	20	4	1		0.036
PS		13	0	1		0.002	3	4	1			16	4	2		
SSB		32	19	1		0.000	28	19	4			60	38	5		
RE		18	3	1		0.009	15	12	1			33	15	2		
	NT DB P	50-69	70-79	80-90	>90		50-69	70-79	80-90	>90		50-69	70-79	80-90	>90	
LSF		4	5	0	1	0.028	12	2	1	0		16	7	1	1	
PS		12	1	0	0	0.030	1	5	2	0	0.54	13	6	2	0	
SSB		30	12	8	1	0.022	28	16	6	1		58	28	14	2	



30M-6HR		30	12	8	1	0.00	28	16	6	1		58	28	14	2	0.018
	24 H SBP	<120	120-129	130-139			<120	120-129	130-139			<120	120-129	130-139		
ERM		25	11	2			28	8	0		0.006	53	19	2		
FHW		23	11	1			32	15	0		0.001	55	26	1		
PS		13	0	1		0.013	6	2	0			19	2	1		0.033
SSB		34	16	2		0.016	33	17	1			67	33	3		
FHH		18	13	2			16	2	1		0.017	34	15	3		
	24 H DBP	<60	60-79	80-90	>90		<60	60-79	80-90	>90		<60	60-79	80-90	>90	
WFV		1	50	1			4	43	4		0.029	5	93	5		0.002
3-6HS/N		1	50	1		0.049	4	42	4			5	92	5		
30MW		1	43	1			3	43	3		0.004	4	86	4		
TTR		1	47	1			3	42	3		0.044	4	89	4		
30M-6HR		1	50	1			4	43	4		0.002	5	93	5		

DBP- diastolic blood pressure; SBP- systolic blood pressure; 3-6HS/N- 3 to 6 hours sleep per night; 30MW- 30 minutes' walk; ERM- eat regular meals; FHH- family history of hypertension; FHW- feeling healthy weight; GSS- getting sufficient sleep; LSF- lots of salty food; PS- passive smokers; RE- regular exercise; SSB-sugar sweetened beverages; TTR- take time to relax; WFV- weekly fruits and vegetables.

Discussion

In this cross-sectional study of university students, the ABP patterns, nocturnal BP changes, BP variability, morning BP surges, and the association between ABP and lifestyle factors were explored. A total of 105 participants were included in this study. A majority of participants had normal or elevated daytime, nighttime, and 24-hour BP, and a few had stage 1 or stage 2 HTN. This trend was also observed with MAP; meanwhile, the PR of most of the participants

was within <60 – 100 bpm. Blood pressure variability was slightly higher in males. Most participants were non-dippers, with very few extreme dippers. A majority of participants who experienced a morning surge in BP had BP values within the normal range. Ambulatory BP was associated with eating lots of salty food (> 5 g salt/day), drinking sugar-sweetened beverages, getting insufficient sleep, and a family history of HTN.

According to the American College of Cardiology/American Heart Association guideline, the thresholds indicating elevated 24-hour, daytime, and nighttime SBP/DBP are 120/75, 120/80, and 105/65 mmHg, respectively. Meanwhile, stages 1 and 2 ambulatory HTN thresholds for 24-hour, daytime, and nighttime SBP/DBP are 125/75 and 130/80 mmHg, 130/80 and 135/85 mmHg, and 110/65 and 120/70 mmHg, respectively (Kronish et al., 2020; Huang et al., 2021; Lewandowska et al., 2023). In this study, 24h average SBP \geq 130 mmHg and DBP \geq 80 mmHg



readings were obtained from 3 and 5 participants, respectively; daytime averages, SBP \geq 135 mmHg and DBP \geq 85 mmHg were 12 and 9 persons, respectively, and nighttime averages, SBP \geq 120 mmHg and DBP \geq 70 mmHg were 43 and 44, respectively. This indicates that more participants had high nighttime BPs than those with high daytime BPs. Daytime BP is subject to the effects of work and environmental stress, activity, body, and arm movement, and the effect of exercise and other activities, whereas these effects are largely absent in night time BP (O'Brien et al., 2018), so everything being equal, the number of participants with high night time BP should have been lower than those with high day time BP. In fact, BP decreases during sleep due to reduced sympathetic nervous system activity (Javaheri & Redline, 2012). High nighttime BP may indicate a pathologic condition and has been associated with cardiovascular disease (Muntner et al., 2019). The reason for the high nighttime BPs observed in this study could be that the participants were students, and most of them were obviously studying at night rather than sleeping. A good number of participants reported sleeping 3 to 6 hours per night. Sleep inadequacy, in the form of lower sleep duration or lower sleep efficiency, is associated with higher daytime SBP, higher nighttime SBP and DBP, and with higher BP the next day (Doyle et al., 2019). In addition, the wearing of the ABP monitor could have affected the quality of sleep and may have affected BP as well.

In physiologic conditions, BP decreases during sleep. Some individuals do not experience the nighttime decrease (non-dipping) during sleep; in some cases, BP rises (risers or reverse dipping), while another group may have a marked decrease in BP during the night (extreme dippers). In this study, non-dippers > dippers > risers > extreme dippers. Risers are usually considered to be at the highest risk (O'Brien et al., 2018). The non-dipping pattern has multiple causes, including increased nocturnal adrenergic activity, poor sleep quality, renal disease, and corticosteroid use. Risers and non-dippers have poorer cardiovascular outcomes than dippers (Kim, 2010). Compared with dippers, those with non-dipping or reverse-dipping BP patterns are reported to have an increased risk of cardiovascular target-organ damage and vascular events such as left ventricular hypertrophy, intima media thickness, and atherosclerotic plaques in women, higher urinary protein excretion, and increased cardiovascular morbidity and mortality (Madin & Iqbal, 2006; Muntner et al., 2019). Higher cardiovascular risk associated with non-dipping is thought to be related to raised sympathetic tone, raised renal sodium reabsorption resulting in higher nighttime BP to drive pressure natriuresis, with the latter responding to low

sodium diet and renal transplantation (Madin & Iqbal, 2006). However, dipping status depends on environmental factors, genetics, daytime activity, and stress, sleep quality, position of the arm relative to the heart, nighttime urinary frequency, and many other factors (Huang et al., 2021), and as such, a diary of a participant's day and nighttime activities could give a clearer perspective of the trend observed in this study.

The day-night BP change is a typical example of circadian variation. In this study, there was no significant difference in variability between males and females, but variability in males was slightly higher. Most people have high SBP and DBP during the day, which decrease steadily as the evening progresses, reaching their lowest levels between midnight and 2 am. They then rise slowly and steadily, becoming steeper at 4 am, and finally reach daytime levels. In most people, the morning surge in BP is less than 20/15 mmHg, and BP values rarely exceed 140/90 mmHg (Madin & Iqbal, 2006). According to (Gosse & Schumacher, 2007), normal SBP surge ranges from 10-30 mmHg, and DBP surge from 7-23 mmHg. In this study, most participants had an average morning BP surge within the normal range. The surge did not seem to be influenced by gender, as was also observed by Gosse & Schumacher (2007). CVD events like myocardial infarction and stroke have been observed to occur between 6 am and noon, which coincides with the period of morning BP surge; thus, the surge in BP during this period may be associated with the risk of CVD (Muntner et al., 2019).

MAP is classified as; 24-hour MAP: < 90 mmHg (normotension); 90 to <92 mmHg (elevated); 92 to <96 mmHg (stage-1 HTN), and \geq 96 mmHg (stage-2 HTN); daytime MAP: 94 mmHg (elevated), 96 mmHg (stage 1 HTN), and 104 mmHg (stage 2 HTN) and nighttime: 80 mmHg (elevated), 82 mmHg (stage 1 HTN) and 88 mmHg (stage 2 HTN) (Melgarejo et al., 2021). In this study, 4 participants had high 24h MAP, 10 had high daytime MAP, and 47 had high nighttime MAP. The high nighttime MAP is consistent with high SBP and DBP recorded in these participants. MAP is the pressure regulated by the constriction and dilation of arterioles, and unlike SBP and DBP, it is consistent across the arterial tree. It allows the blood in circulation to supply key organs with oxygen and crucial nutrients. Lower MAP may be deleterious in unstable hemodynamics, while higher levels are associated with target organ damage, cardiovascular, and cerebrovascular diseases (Karahana & Zor, 2024). Physiologically, BP and blood flow exhibit a pulsatile component, with SBP and DBP representing the peak and trough of BP oscillations around MAP, which drive organ



perfusion. When peripheral resistance increases due to rarefaction or remodeling of arterioles, MAP rises, with parallel increases in SBP and DBP (Asayama et al., 2023). The mean 24H, daytime, and night-time PR for a majority of the participants was within 60 – 100 bpm, which is indicative of the typical normal PR range in adults (Sobieraj et al., 2021).

Across the various lifestyle factors, there were individuals with normal BP, some with elevated BP, and others with HTN, indicating that lifestyle factors affect the BP of individuals differently because of genetic predisposition, age, gender, ethnicity, preexisting health conditions, and environmental factors (Takase et al., 2025). The association between BP and high salt intake is in line with (Kazi, 2025), who reported that chronic high-salt intake can cause the hormonal and neural salt-regulatory systems to adapt to the increased sodium load, leading to sodium accumulation in the body and HTN. Previous studies have shown that consumption of sugar-sweetened beverages is associated with higher BP and higher incidence of HTN (Malik et al., 2014). Family history of HTN is a simple tool for early detection of young adults potentially at higher risk of HTN (Kunnas & Nikkari, 2023).

Conclusion

A combination of ABP monitoring and examination of lifestyle patterns is crucial in tracking BP changes and hence the cardiovascular health of young adults.

Limitations

This study's limitations include a small sample size, which may limit generalizability, and potential inaccuracies in self-reported data regarding lifestyle patterns and family history of HTN. Although self-reported data are useful, they can be affected by recall bias and social desirability, reducing the precision of the findings. In addition, some young adults may not be aware of their family's HTN status if their relatives have not yet been diagnosed or have not disclosed their condition.

Recommendation

There is a great need for widespread ABP monitoring of healthy young adults coupled with education on healthy lifestyle patterns in order to prevent future cardiovascular disease.

List of abbreviations

%DBPD- percentage change in diastolic blood pressure;
%SBPD- percentage change in systolic blood pressure;

6HS/N- 3 to 6 hours sleep per night; **24HDBP**- 24 hours diastolic blood pressure; **24HMAP**- 24 hours mean arterial blood pressure; **24HPR**- 24 hours pulse rate; **24HSBP**- 24 hours systolic blood pressure; **30MW**- 30 minutes' walk; **ABP**- ambulatory blood pressure; **ABPM**- ambulatory blood pressure monitoring; **DBP**- diastolic blood pressure; **DT**- daytime; **DTDBP**- daytime diastolic blood pressure; **DTMAP**- daytime mean arterial pressure; **DTPR**- daytime pulse rate; **DTSBP**- daytime systolic blood pressure; **ERM**- eat regular meals; **FHH**- family history of hypertension; **FHW**- feeling healthy weight; **GSS**- getting sufficient sleep; **HTN**- Hypertension; **LMIC**- low- and middle-income countries; **LSF**- lots of salty food; **NT**- nighttime; **NTDBP**- nighttime diastolic blood pressure; **NTMAP**- nighttime mean arterial pressure; **NTPR**- nighttime pulse rate; **NTSBP**- nighttime systolic blood pressure; **PS**- passive smokers; **RE**- regular exercise; **SBP**- systolic blood pressure; **SSB**-sugar-sweetened beverages; **TTR**- take time to relax; **WFV**- weekly fruits and vegetables.

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Data availability

The data used or analyzed in this study are available from the corresponding author on request.

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Conflict of interest

The authors declare that they have no conflict of interest.

Author contributions

Charlotte Mungho Tata – conceptualization, supervision, data analysis, writing of draft, review and editing; **Wisdom Igang** – investigation; **Christopher Tume** – supervision;



Benedicta Ngwenchi Nkeh-Chungag – conceptualization, review and editing.

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