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Determinants of Blood Pressure Variability in Individuals with Essential Hypertension: A Survey-Based Study

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Abstract

Background: Blood pressure variability (BPV) in hypertensive patients is implicated as a remarkable feature leading to additional cardiovascular complications. The aim of the study was to identify the determinants influencing BPV among patients with essential hypertension seen at the Cardiology department of the faculty of medicine, University of Alexandria, Egypt. **Methods:** This was a descriptive cross-sectional hospital-based study conducted from August 2019 to November 2019. All the eligible patients were made to fill out a standard questionnaire to obtain family and personal clinical history and undergo routine physical examination, laboratory tests and 24-hour ambulatory blood pressure monitoring. BPV was summarized as the standard deviation (SD) of all-day systolic and diastolic BP in both normal patients (with SD < 11) and abnormal patients (with SD ≥ 11). **Results:** Out of a total of 114 patients, 18 (15.8%) non-hypertensive patients were included in the control group and the remaining 96 (84.3%) were classified based on the degree of hypertension. BPV in all these patients was found to be significantly related to the male gender, a mild or moderate degree of hypertension, high prevalence of non-dipping, diabetes, use of beta-blockers as antihypertensive medication, heart rate variability, BMI, and increased day-time variability. **Conclusion:** Variability in blood pressure influenced by different intrinsic and extrinsic factors plays an important role in the management of hypertension. In order to reduce the burden of disease and for a better quality of life for hypertensive patients, it is important that physicians start considering lowering BPV in addition to reducing physiological BP levels.

Keywords

Blood Pressure Variability, Determinants, Diastolic, Essential Hypertension, Systolic

1. Introduction

Several studies have revealed that blood pressure variability (BPV) is a major risk factor that independently contributes to the development of cardiovascular diseases (CVD). It may also lead to target organ damage (especially involving blood vessels, kidneys, and heart), increased mortality, and morbidity in people with hypertension [1] [2] [3] [4]. BPV is a dynamic variable, which can be simply defined as spontaneous fluctuations in BP over a period of time [5] and may be categorized as 1) short-term (estimated as beat-to-beat, minute-to-hour daytime/night-time changes), 2) mid-term (day-to-day), and 3) long-term (over a period of months, and seasons) variability. BPV is generally expressed as a standard deviation (SD) of 24-hour mean BP (systolic or diastolic). Various intrinsic and extrinsic factors influence BPV, and the magnitude of these variations differs among different individuals. These can be classified as a) physiological factors, including different cardiovascular control mechanisms such as autonomic, neural, humoral mechanisms, and alterations in regulatory mechanisms mainly related to arterial stiffness; b) behavioral factors such as physical and/or mental activity, body posture, and exercise; c) demographic, lifestyle, and environmental factors such as gender, age, race, body mass index (BMI), high salt diet, smoking, alcohol, antihypertensive medications, temperature, and seasonal variations; d) comorbidities such as primary and secondary hypertension, diabetes, chronic kidney disease, stroke, autonomic neuropathy, and others Hano and Koike 2022, [2] [5] [6] [7] [8] [9]. One of the best tools that enable the measurement of BPV precisely is 24-hour ambulatory blood pressure monitoring (ABPM) [10]. This helps in evaluating even short-term BP variability with a measurement gap of fewer than 15 minutes, or any abnormal BP patterns, over a period of 24 hours. Moreover, identifying white-coat or masked hypertension in an individual (with large discrepancies between home BP and clinic BP readings) and assessing the efficacy of antihypertensive treatment are rendered easy with ABPM [11] [12].

The therapeutic management for hypertension should be well-planned and considered for evaluating BP fluctuations within a patient in addition to mean BP. Furthermore, the therapy should not only focus on reducing elevated BP but also help decrease BPV. Different drug agents available to date for treating hypertension include calcium channel blockers (CCBs), angiotensin receptor blockers (ARBs), angiotensin-converting enzyme inhibitors (ACEIs), beta-blockers (BBs), and diuretics [13] [14] [15]. Despite these therapies, it is difficult to achieve controlled BP in clinical practice. Understanding the various variables or factors that can potentially affect BPV in hypertensive patients in a hospital setting could help improve patient outcomes, thereby reducing the overall burden of the disease. Therefore, a real-world evidence-based study was designed to evaluate the determinants of BPV in patients with essential hypertension presented to the cardiology department of our hospital.

2. Subjects and Methods

A total of 114 patients presenting with symptoms of essential hypertension to the cardiology department of Alexandria University Hospital, Egypt, either as outpatients or during hospitalization, were enrolled in the present cross-sectional study. Essential hypertension was defined as a systolic BP (SBP) ≥ 140 mmHg and diastolic BP (DBP) ≥ 90 mmHg. The inclusion/exclusion criteria for the selection of patients have been provided in Table 1.

Informed consent was received from all the patients participating in the study. Thereafter, all the eligible patients underwent the following procedures [16]: 1) Completing a standard questionnaire to obtain family and personal clinical histories, along with confirmation from medical records at the hospital with particular attention to: a) previous levels and time-duration of high BP; b) indications of secondary hypertension; c) risk factors, including lifestyle and dietary habits d) any history or current symptoms of organ damage; e) current and previous antihypertensive therapy; f) personal, family and environmental factors; 2) General physical check-up for assessing secondary hypertension, organ damage, and visceral obesity included in-clinic BP measurement done twice in each visit, for two visits being one weak apart; 3) Laboratory examination included routine tests such as complete blood count, blood glucose level, serum electrolytes (sodium, potassium, and magnesium), serum urea, creatinine and creatinine clearance; standard 12 lead ECG for evidence of left ventricular hypertrophy; conventional transthoracic echocardiography for detection of exclusion criteria; and 24-hour

Table 1. Inclusion and exclusion criteria for selecting patients.

Inclusion Criteria
Patients were classified into four groups according to their blood pressure level:
• **Group 1** with mild hypertension (systolic BP: 140 - 159 mmHg, diastolic BP: 90 - 99 mmHg)
• **Group 2** with moderate hypertension (systolic BP: 160 - 179 mmHg, diastolic BP: 100 - 109 mmHg)
• **Group 3** with severe hypertension (systolic BP: ≥180 mmHg, diastolic BP: ≥110 mmHg)
• **Group 4** with normal BP level as a control group
Exclusion Criteria
Patients with secondary hypertension and/or with
• Heart failure
• Valvular heart disease
• Cardiomyopathy with left ventricle ejection fraction (LVEF) < 50%
• Cerebrovascular stroke or transient ischemic attacks
• Renal failure
• Endocrinal diseases
• Cancer
• Pregnancy

ABPM. All the study procedures were conducted in accordance with the Declaration of Helsinki and the Institutional Ethics Committee.

BP Assessment

All the BP measurements (in-clinic or ambulatory) were taken in accordance with the protocol recommended by the European Society of Hypertension [17].

In-clinic BP was measured using a mercury sphygmomanometer having an appropriate-sized cuff, with the patient in a seated position. The first and fifth Korotkoff's sound was the criteria to identify systolic and diastolic values, respectively.

Twenty-four-hour ABPM was performed using a validated and calibrated oscillometric device having cuffs of appropriate sizes (Bravo CE 0413; SunTech Medical Instrument Inc. with a SunTech cuff). Subjects were instructed to take all their usual medicines, carry out their usual daily activities, but to avoid vigorous exercise. Ambulatory BP [mmHg (kPa)] was measured for a period of 24-hours with the device programmed to take BP readings at every 60-minute intervals without interfering with the subject's activity or sleep. The mean of three consecutive readings was used for further analysis. During measurements, subjects were told not to move and talk, keep their arm immobile and relaxed, and to breathe normally. They were also asked to keep a record of all their daily activities or events such as eating, exercise, time of medicine intake, emotional stress, posture, and any indications (e.g., dizziness) related to BP, and timings of sleeping and waking up [18]. Readings obtained from ABP monitoring were carefully elucidated with respect to the patient's recorded information. Reference ABP values for adults and interpretation of the results have been given in **Table 2**.

For minimizing the consequences of recording errors while monitoring ABP, the within-subject mean and SD were used to evaluate BP and BPV. Taking the night time dipping into account, daily mean and SD were calculated as day time mean, day time SD (for awake time), night-time mean, and night time SD (for asleep time) using the following 2 formulas:

$$\text{Daily mean} = (\text{day time mean} \times \text{AT} + \text{night time mean} \times \text{ST})/(\text{AT} + \text{ST}) \text{ and}$$

$$\text{Daily SD} = (\text{day time SD} \times \text{AT} + \text{night time SD} \times \text{ST})/(\text{AT} + \text{ST})$$

Table 2. Reference ABP values for adults and interpretation of the results.

- 24-hour mean < 115/75 mmHg (hypertension threshold 130/80 mmHg).
- Day time (awake) < 120/80 mmHg (hypertension threshold 135/85 mmHg).
- Night time (asleep) < 105/65 mmHg (hypertension threshold 120/75 mmHg).
  - ✓ Ambulatory BP values above 'normal' and below thresholds for hypertension are considered 'high normal'. Night time (sleeping) average systolic and diastolic BP, both should be at least 10% lower than average day time (awake).
  - ✓ Blood pressure load (percentage of time that BP readings exceed hypertension threshold during 24 hours) should be <20%.
  - ✓ Blood pressure variability, maximum systolic BP, and morning BP surge should also be taken into account (and targeted by treatment). Treatment targets based on ABP should be lower than the targets for clinic BP readings (e.g. for clinic BP of 140/90, day time ABP equivalent is 136/872).

*where AT and ST stand for awake time and sleeping time in hours.

Statistical Analysis

Data were analyzed by the Statistical Package for Social Sciences R (SPSS Inc., Chicago, USA) version 16.0 program. Continuous variables were summarized as mean (day time, night time, or 24-hour SBP and DBP and heart rate) and SD (BPV), while categorical variables were summarized as percentages. A chi-square test compared data between the different groups. P-values ≤ 0.05 and 95% confidence interval (CI) were considered significant.

3. Results

Out of a total of 114 individuals enrolled in the study, 18 (15.8%) patients were not found to be hypertensive; therefore, they were included in the control group. According to the inclusion criteria, the remaining 96 (84.3%) hypertensive patients were classified based on the degree of hypertension (mild, moderate, and severe) (Figure 1).

The distribution of all these cases (N = 114) based on the types of medications [ARBs, ACEIs, CCBs, BBs, and diuretics] that they received was also studied. It was found that the majority of patients (38.6%) were on ACEI/ARBS, while only 7% were on diuretics (Table 3).

To study BPV summarized as SD of both (I) SBP and (II) DBP (as explained in the methodology), patients were classified into 2 groups; Group 1: normal patients (with SD < 11), Group 2: abnormal patients (with SD ≥ 11). For all-day SD SBP, the total number of patients in Group 1 was 38 and 76 in Group 2. All-day SD DBP had a total of 54 patients in Group 1 while 60 in Group 2.

Comparison of SD of All-Day SBP and DBP between Group 1 (Normal) and Group 2 (Abnormal)

1) *Based on Gender*

For SD SBP, the patients in both Group 1 and Group 2 showed a higher percentage of males as compared to females with no statistical significance (P =

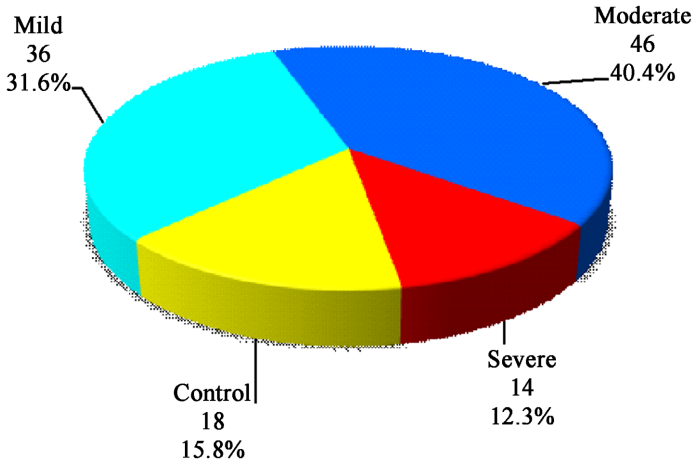

Figure 1. Distribution of studied cases (N = 114) based on the absence and presence of hypertension; stratified according to the degree of hypertension.

Table 3. Distribution of studied cases (N = 114) according to the type of medication they received.

Type of medication	Number of patients (N)	%
Not on medications	50	43.9
ACEI/ARBS	44	38.6
CCBs	30	26.3
BBs	26	22.8
Diuretics	8	7

Table 4. Relation of gender to the standard deviation of all-day (a) systolic and (b) diastolic blood pressure values between Group 1 (normal) and Group 2 (abnormal).

(a)

SD all-day SBP			Normal (Group 1)	Abnormal (Group 2)	χ^2	P-value
Gender	Male	No.	20	46	0.648	0.421
		%	52.6%	60.5%		
	Female	No.	18	30		
		%	47.4%	39.5%		

(b)

SD all day DBP			Normal (Group 1)	Abnormal (Group 2)	χ^2	P-value
Gender	Male	No.	26	40	3.998	0.046*
		%	48.1%	66.7%		
	Female	No.	28	20		
		%	51.9%	33.3%		

0.421) (Table 4(a)). However, for SD DBP, the patients in Group 2 showed a significantly higher male ratio (66.7% versus 33.3%; P = 0.046) (Table 4(b)).

2) ***Based on Age***

For both SD SBP and SD DBP, a higher mean value of age was seen among patients in Group 1 (52.63 ± 9.99 and 55.07 ± 11.13 respectively) as compared to Group 2 (51.95 ± 12.74 and 49.57 ± 11.96 respectively), but with no statistical significance (Table 5(a) & Table 5(b)).

3) ***Based on the Degree of Hypertension***

A significantly higher number of patients with abnormal SD SBP and DBP showed a strong association with mild (34.2% and 36.7, respectively) and moderate (50% and 43.3% respectively) degree of hypertension (χ^2 = 30.904*; P < 0.001* and χ^2 = 8.108*; P = 0.044 respectively). Only 2 (2.6%) patients having abnormal SD SBP and 4 (6.7%) patients with abnormal SD DBP belonged to the category of patients with no hypertension (control) (Figure 2(a) & Figure 2(b)).

Table 5. Relation of age to the standard deviation of all-day (a) systolic and (b) diastolic blood pressure values between Group 1 (normal) and Group 2 (abnormal).

(a)

SD all-day SBP		Range			Mean ±	SD	T-test	P-value
Age	Normal (Group 1)	30.00	-	69.00	52.63 ±	9.99	0.084	0.773
	Abnormal (Group 2)	19.00	-	83.00	51.95 ±	12.74		

(b)

SD all-day DBP		Range			Mean ±	SD	T-test	P-value
Age	Normal (Group 1)	30.00	-	83.00	55.07 ±	11.13	6.432	0.113
	Abnormal (Group 2)	19.00	-	70.00	49.57 ±	11.96		

*T-test: Student T-test.

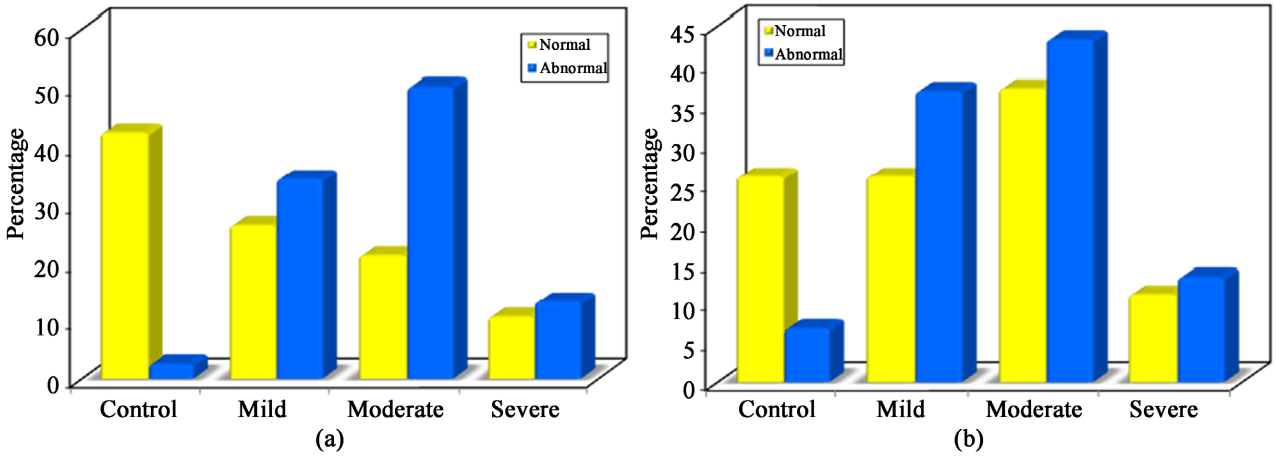

Figure 2. Comparison of the standard deviation of all-day (a) systolic and (b) diastolic blood pressure values between Group 1 (normal) and Group 2 (abnormal), based on the degree of hypertension.

4) *Based on the Presence or Absence of Diabetes*

Among patients having abnormal SD SBP, 28.9% were diabetic, with 63.6% of them presented with insulin-dependent diabetes mellitus (IDDM) (Table 6(a)). While among patients with abnormal SD DBP, 33.3% were diabetic, and 80% of them had IDDM (Table 6(b)).

Among both diabetic and non-diabetic patients, those with hypertension showed higher values of SD all-day systolic blood pressure with a significant relation of a P wave < 0.001 (Table 7).

5) *Based on Dipping*

Among patients having abnormal SD SBP, 60.5% were dippers (P = 0.182), while among those having abnormal SD DBP, 66.7% were dippers with no statistical

Table 6. Comparison of the standard deviation of all-day (a) systolic and (b) diastolic blood pressure values between Group 1 (normal) and Group 2 (abnormal), based on the presence or absence of diabetes.

(a)

	SD all-day SBP					
	Normal (Group 1) (N = 38)		Abnormal (Group 2) (N = 76)		χ^2	P-value
	No.	%	No.	%		
Diabetes						
Non diabetic	32	84.2	54	71.1	2.367	0.124
Diabetic	6	15.8	22	28.9		
IDDM	4	66.7	14	63.6	0.019	$^{FE}P = 1.000$
NIDDM	2	33.3	8	36.4		

(b)

	SD all-day DBP					
	Normal (Group 1) (N = 54)		Abnormal (Group 2) (N = 60)		χ^2	P-value
	No.	%	No.	%		
Diabetes						
Non diabetic	46	85.2	40	66.7	5.260*	0.022*
Diabetic	8	14.8	20	33.3		
IDDM	2	25.0	16	80.0	7.529*	$^{FE}p = 0.011$*
NIDDM	6	75.0	4	20.0		

χ^2: value for Chi-square; FE: Fisher Exact test; *: Statistically significant at P ≤ 0.05; IDDM: Insulin-dependent diabetes mellitus; NIDDM: Non-insulin-dependent diabetes mellitus.

Table 7. Comparison between the two studied groups (control and hypertension) according to SD all-day systolic BP in diabetics and non-diabetic patients.

SD all-day SBP	Control (I)	Hypertension (II)	T-test	P-value
Not diabetics	**(N = 16)**	**(N = 70)**		
Min. - Max.	7.0 - 16.00	7.0 - 23.0		
Mean ± SD.	9.88 ± 2.75	13.91 ± 3.64	4.168*	<0.001*
Median	9.0	14.0		
Diabetics	**(N = 2)**	**(N = 26)**		
Min. - Max.	9.0 - 9.0	10.0 - 21.0		
Mean ± SD.	9.0 ± 0.0	15.15 ± 3.22	9.742*	<0.001*
Median	9.0	15.0		

T-test: Student T-test; *: Statistically significant at P ≤ 0.05.

significance (P = 0.107) (Table 8(a) & Table 8(b)).

6) ***Based on Medication***

A significantly higher number of patients, 48 (63.2%) from Group 2, while only 16 (42.1 %) patients from Group 1 with SD SBP were found to be on antihypertensive medications (χ^2 = 4.560*; P = 0.033). However, 34 (56.7%) patients with abnormal and 30 (55.6%) patients with normal SD DBP were on hypertensive medications (χ^2 = 0.014*; P = 0.905). Distribution of these patients between normal and abnormal groups according to the type of antihypertensive treatment (diuretic, ACE/ARBS, CCB, and BB) has been shown in Table 9(a) & Table 9(b). A total of 28 (75%) patients (from both Group 1 and Group 2) taking BB showed significantly high SD for systolic blood pressure (χ^2, P = 0.014).

7) ***Based on Mean Arterial Blood Pressure (MABP) and Mean Heart Rate (HR)***

MABP in patients with abnormal SD SBP and DBP were significantly higher (99.82 ± 9.46 and 100.33 ± 9.74 respectively) than patients with normal SD SBP and DBP (90.00 ± 7.00 and 92.33 ± 8.17 respectively) (P = 0.001*) (Table 10(a) & Table 10(b)). Mean ± SD HR was significantly higher in Group 2 DBP (81.57 ± 9.81) than Group 1 DBP (73.70 ± 10.35) (P = 0.001*).

8) ***Based on BMI***

Mean ± SD BMI was higher in patients with abnormal SD SBP and DBP (33.21 ± 5.97 and 34.03 ± 7.68, respectively) than normal SD SBP and DBP

Table 8. Comparison of the standard deviation of all day (a) systolic and (b) diastolic BP between Group 1 (normal) and Group 2 (abnormal), based on dipping.

(a)

	SD all-day SBP				χ^2	P-value
	Normal (Group 1) (N = 38)		Abnormal (Group 2) (N = 76)			
	No.	%	No.	%		
Dipping						
Non dipper	20	52.6	30	39.5	1.781	0.182
Dipper	18	47.4	46	60.5		

(b)

	SD all-day DBP				χ^2	P-value
	Normal (Group 1) (n = 54)		Abnormal (Group 2) (n = 60)			
	No.	%	No.	%		
Dipping						
Non-dipper	26	48.1	20	33.3	2.592	0.107
Dipper	28	51.9	40	66.7		

*χ^2: Value for Chi-square.

Table 9. Comparison of the standard deviation of all day (a) systolic and (b) diastolic BP between Group 1 (normal) and Group 2 (abnormal), based on Type of Medications

(a)

	SD all-day SBP				χ^2	P
	Normal (Group 1) (N = 38)		Abnormal (Group 2) (N = 76)			
	No.	%	No.	%		
Medication						
Not on medication	22	57.9	28	36.8	4.560*	0.033*
Medication	16	42.1	48	63.2		
Type of medication						
Diuretic	2	12.5	6	12.5	0.269	0.717
ACEI/ARBS	12	75.0	34	70.8	1.822	0.177
CCB	10	62.5	18	37.5	0.095	0.758
BB	4	25.0	24	50.0	6.060*	0.014*

(b)

	SD all-day DBP				χ^2	P-value
	Normal (Group 1) (N = 54)		Abnormal (Group 2) (N = 60)			
	No.	%	No.	%		
Medication						
Not on medication	24	44.4	26	43.3	0.014	0.905
Medication	30	55.6	34	56.7		
Type of medication						
Diuretic	2	6.7	6	17.6	1.727	0.277
ACE/ARBS	20	66.7	26	76.5	0.468	0.494
CCB	12	40.0	16	47.1	0.303	0.582
BB	12	40.0	16	47.1	0.303	0.582

χ^2: Value for Chi-square; FE: Fisher Exact test; *: Statistically significant at P ≤ 0.05; ACEI (Angiotensin-converting enzyme inhibitor); ARBS (Angiotensin receptor blockers); CCB (Calcium channel blockers); BBs (Beta-blockers).

(29.26 ± 6.41 and 32.41 ± 11.15, respectively) showing statistical significance (Z = 10.556; P = 0.002* and Z = 2.486; P = 0.013*, respectively) (Figure 3(a) & Figure 3(b)).

9) ***Based on Average SBP and DBP***

The relation of average systolic (all-day, day-time, and night-time) values in both Group 1 SD SBP/SD DBP and Group 2 SD SBP/DBP have been shown in Table 11(a) & Table 11(b). Higher values of mean and median average systolic

were observed for all-day (P = 0.032) and day-time (P = 0.013) abnormal SBP group with statistical significance. Similarly, higher values of SDs mean and median

Table 10. Comparison of the standard deviation of all day (a) systolic and (b) diastolic BP between Group 1 (normal) and Group 2 (abnormal), based on MABP and average HR.

(a)

SD all-day SBP		Range	Mean ± SD	T-test	P-value
Average MABP	Normal (Group 1)	83.00 - 112.00	90.00 ± 7.00	32.089	0.001*
	Abnormal (Group 2)	87.00 - 131.00	99.82 ± 9.46		
Average HR	Normal (Group 1)	61.00 - 95.00	75.53 ± 10.59	2.674	0.105
	Abnormal (Group 2)	61.00 - 101.00	79.00 ± 10.74		

(b)

SD all-day DBP		Range	Mean ± SD	T-test	P-value
Average MABP	Normal (Group 1)	83.00 - 112.00	92.33 ± 8.17	22.286	0.001*
	Abnormal (Group 2)	86.00 - 131.00	100.33 ± 9.74		
Average HR	Normal (Group 1)	61.00 - 95.00	73.70 ± 10.35	17.333	0.001*
	Abnormal (Group 2)	65.00 - 101.00	81.57 ± 9.81		

T-test: Student T-test; *: Statistically significant at P ≤ 0.05; MABP: Mean Arterial Blood Pressure; HR: Heart Rate.

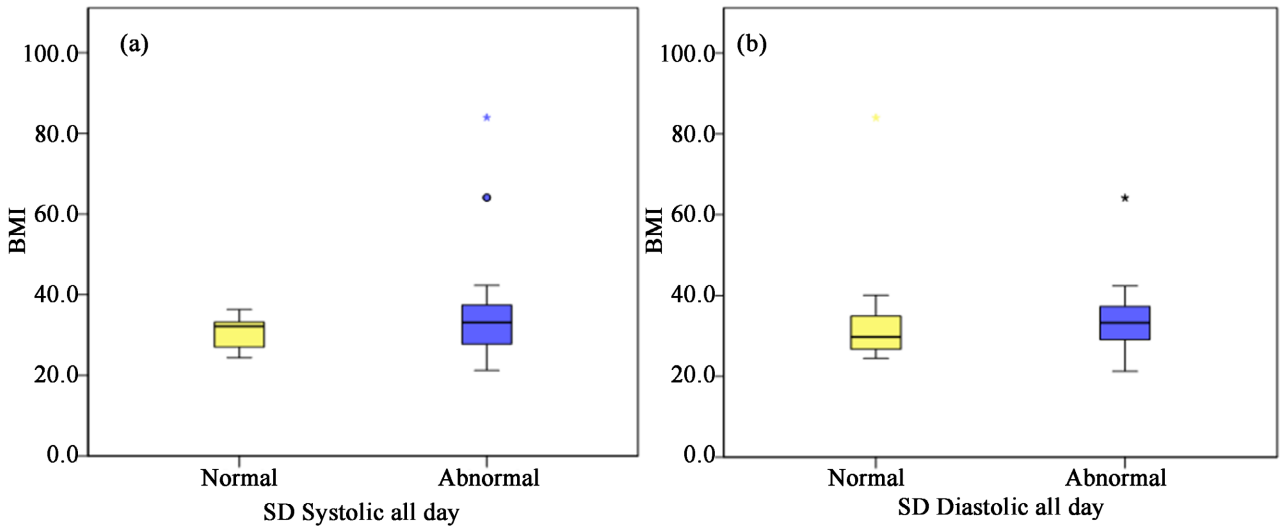

Figure 3. Comparison of the standard deviation of all day (a) systolic and (b) diastolic BP between Group 1 (normal) and Group 2 (abnormal), based on Body mass index (BMI).

Table 11. Comparison of the standard deviation of all day (a) systolic and (b) diastolic BP between Group 1 (normal) and Group 2 (abnormal) based on average systolic BP.

(a)

Average systolic	SD all-day SBP		T-test	P-value
	Normal (Group 1) (N = 38)	Abnormal (Group 2) (N = 76)		
All-day				
Min. - Max.	110.0 - 149.0	102.0 - 162.0		
Mean ± SD.	126.16 ± 11.70	132.05 ± 14.53	2.171*	0.032*
Median	124.0	132.50		
Day-time				
Min. - Max.	115.0 - 151.0	96.0 - 161.0		
Mean ± SD.	127.79 ± 10.68	134.24 ± 13.88	2.513*	0.013*
Median	124.0	135.0		
Night-time				
Min. - Max.	100.0 - 157.0	103.0 - 161.0		
Mean ± SD.	121.95 ± 14.88	122.21 ± 15.66	0.086	0.932
Median	120.0	119.0		

(b)

Average systolic	SD all-day DBP		T-test	P-value
	Normal (Group 1) (N = 54)	Abnormal (Group 2) (N = 60)		
All day				
Min. - Max.	110.0 - 161.0	102.0 - 162.0		
Mean ± SD.	130.07 ± 15.15	130.10 ± 12.77	0.010	0.992
Median	124.0	129.0		
Day time				
Min. - Max.	115.0 - 161.0	96.0 - 155.0		
Mean ± SD.	131.96 ± 14.49	132.20 ± 12.07	0.094	0.925
Median	124.0	134.0		
Night time				
Min. - Max.	100.0 - 161.0	103.0 - 157.0		
Mean ± SD.	123.74 ± 16.58	120.67 ± 14.11	1.069	0.287
Median	120.0	119.0		

T-test: Student T-test; *: Statistically significant at $P \leq 0.05$.

were observed for all-day and day-time abnormal DBP group but were non-significant.

Distribution of the Abnormal SD SBP and DBP According to Day-Time and Night-Time

Higher mean values of both abnormal systolic (15.18 ± 3.31) and diastolic

(15.10 ± 3.69) BP were observed in the day-time and showed statistical significance ($P \leq 0.001$) (Figure 4(a) & Figure 4(b)).

4. Discussion

ABPM is increasingly being approved for routine use in clinical practice [18] [19]. The evidence that ABPM accurately reflects information regarding BPV over cuffed blood pressure monitoring (CBPM) has been gaining importance over the past several years. Twenty-four-hour or all-day ABPM provides actual blood pressure readings of a patient during usual daily activities, rather than in an unrealistic environment of a clinic or office. This may improve the physician's ability to predict cardiovascular risk and assess the efficacy of antihypertensive medication. Additionally, this would prevent irrational prescribing based on one or a few CBPMs limited to only a short period of the diurnal pattern [20]. ABPM and, in particular, nocturnal blood pressure readings may have prognostic implications [21].

The present study evaluated the determining factors such as age, gender, diabetes, dipping, grade of hypertension, antihypertensive medications, MABP and mean HR, BMI, average systolic BP, and their relation with BPV (measured through SDs of all-day SBP or all-day DBP) in patients with essential hypertension.

The current study demonstrated that in comparison to females, males had a significantly higher BPV for diastolic BP. The plausible explanation for this could be more sedentary lifestyle patterns or working environments for women. Also, both men and women may react differently to work-related or psychosocial stress. Our results were found comparable to other studies [22] [23]; however, it was contrary to a finding by Ninios *et al.* (2008), who reported that women exhibited a higher prevalence of hypertension as compared to men [24]. It is well known from a few previous studies that age-related changes in the cardiovascular systems increase BPV with age [25] [26]. Dupont *et al.* (2000), found that in patients younger and greater than 30 years, diastolic, and not systolic BPV correlated with age [27]. However, our study demonstrated no statistically significant

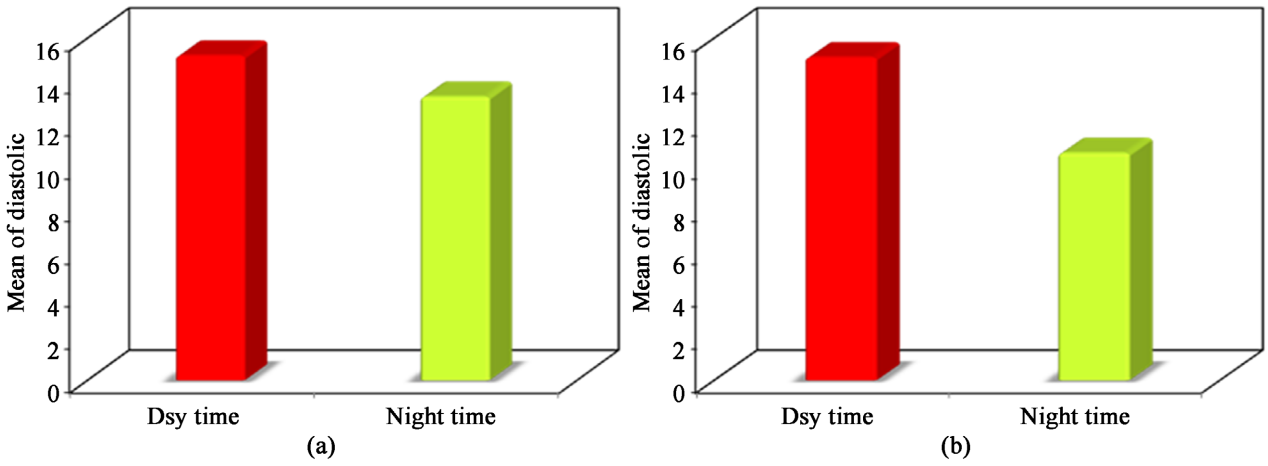

Figure 4. Distribution of the abnormal (a) SD systolic BP (b) SD diastolic BP according to day-time and night-time.

relationship between age and BPV or standard deviation of SBP or DBP. This may be because of the limited number of patients in our study or that the outcome of variability was influenced by study design, the methods used for blood pressure measurement, and statistical expression of variability.

The absence of dip in nocturnal pressure (as in non-dippers) may place patients at a high risk of CVD [28]. Among our studied individuals, a high prevalence of non-dippers was observed with 43.86% patients for systolic and 40.35% for diastolic pressure. This was quite similar to a study done by Tartan *et al.* (2006), which found that the majority (61.4%) of their hypertensive patients were non-dippers [29].

The pattern of circadian variability of blood pressure in diabetic patients is different from that of non-diabetics [30]. The present study showed a significant relation of DBP with IDDM than with the non-insulin-dependent group. Moreover, a higher BPV of all-day systolic SD was observed in hypertensive diabetic patients than non-diabetics, which correlated well with many studies [30] [31] [32].

Among all the antihypertensive agents, CCBs have been found to reduce BPV the most [33]. CCBs, in combination with ACE-inhibitors, have also shown to decrease BPV more in comparison to diuretics plus beta-blockers [34]. Treatment with amlodipine and indapamide sustained-release tablets have shown to significantly reduce BPV in patients, probably attributable to lowering levels of BP or enhancing the regulation of the autonomic nervous system or both [35]. Our results were also consistent with previous studies and showed that the BPV (measured as SD SBP) was least in patients on CCBs.

The current study observed a significant relationship between heart rate variability and BPV (SD systolic and diastolic BP) and found it comparable to other findings [36] [37].

Significant correlations have been seen between BMI and mean 24-hour ABP variability with confirmed hypertension found to be higher in overweight individuals than compared with normal-weight subjects [38] [39]. This is similar to the results obtained in our study with significantly higher Mean ± SD values of BMI in patients with abnormal SD SBP and DBP.

Increased variability in day-time BP, evaluated as the abnormal SD SBP and DBP in our study, has been found to be associated with severe cardiovascular complications in hypertensive patients [40]. However, there were a few limitations in our study. This was a single-center study. The proportion of data was collected from free text fields, and may be biased and as such represented an underestimate of the findings or clinical variables.

5. Conclusion

In hypertensive patients, cardiovascular risk and multiple organ damage are not only related to the blood pressure levels, but also to BPV. Therefore, it would be reasonable to include 24-hour ABPM as a tool for assessing BPV in the current

diagnostic armamentarium of managing hypertension. Through this study, we could also identify several significant factors influencing BPV, such as male gender, mild or moderate degree of hypertension, high prevalence of non-dipping, diabetes, use of beta-blockers, heart rate variability, BMI, and increased day-time variability in patients with essential hypertension. A better understanding of these determinants may add to significant prognostic information about hypertensive patients.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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