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ORIGINAL RESEARCH

Evaluating Blood Pressure Variability in Type 2 Diabetic Patients: An Insight into Non-Dipping Patterns and Their Clinical Implications

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Background: Hypertension (HTN) is prevalent in individuals with type 2 Diabetes Mellitus (T2DM), doubling the risk of developing chronic complications. Despite normal routine checks, many patients with diabetes exhibit abnormal blood pressure (BP) profiles identified by 24-hour ambulatory Blood Pressure monitoring (ABPM). This study aimed to analyse blood pressure variability in patients with diabetes to enhance current knowledge and improve clinical practice.

Methods: This cross-sectional study obtained ethical approval from Jazan University and involved 58 patients with type 2 Diabetes Mellitus (T2DM) who adhered to the strict inclusion and exclusion criteria. Comprehensive clinical and laboratory data, including demographic, clinical, and essential laboratory parameters, were collected using a standardized form. Blood Pressure (BP) was meticulously monitored using the Sun Tech Oscar 2 ABPMR device, with measurements commencing between 8 am and 10 am, extending over 24 hours. The study calculated averages and evaluated systolic and diastolic percentage dipping during 24-hour, daytime, and night-time intervals. Participants classified as "dippers" experienced a BP reductions of at least 10%.

Results: Fifty-eight normotensive T2DM patients, with a mean age of 45.51 ± 6.7 years, were monitored over 24 months. Among the 58 individuals assessed using ABPM, a non-dipping pattern was observed in 45 participants (77.58%), whereas 13 (22.41%) exhibited a dipping pattern. Postprandial and fasting blood sugar levels were distinct; the dipper group demonstrated better post-meal glucose control (p=0.02), whereas the non-dipper group had superior fasting glucose control (p=0.04). The dipper group showed a higher 24-hour average systolic BP (p=0.00) and increased dipping percentages for systolic and diastolic BP during sleep.

Conclusion: Over 77% of ABPM-evaluated individuals showed non-dipping patterns, with a higher BMI being strongly associated. Laboratory findings revealed distinct variations in the postprandial and fasting blood sugar levels, suggesting a potential genetic predisposition.

Keywords: hypertension, T2DM, ABPM, cardiovascular, haemodynamic

Introduction

Type 2 diabetes mellitus (T2DM) and hypertension (HTN) are highly prevalent comorbidities that frequently coexist, compounding the risk of developing chronic complications. Among diabetic patients, HTN occurs at a rate twice that of non-diabetic individuals, significantly contributing to the emergence of cardiovascular and renal complications.[1] Effective management of these conditions is crucial to mitigate the associated risks, particularly through the continuous monitoring of blood pressure.[2]

Ambulatory blood pressure monitoring (ABPM) offers a detailed and dynamic assessment of BP variations over a 24-hour period, capturing measurements during both daytime and night-time intervals.[3] Unlike conventional clinical BP

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measurements, ABPM provides a robust correlation with target organ damage and offers valuable insight into circadian BP patterns. The calculation of 24-hour BP variability, utilizing the standard deviation of mean BP measurements, serves as an indirect indicator of autonomic circulation regulation, which is often impaired in individuals with diabetes.[4] Morning hypertension, more prevalent among diabetic patients, is a significant predictor for the progression of diabetic nephropathy.[5]

T2DM significantly affect cardiovascular autonomic functions, leading to impaired autonomic regulation and interrupted blood pressure homeostasis, which are critical factors in cardiovascular outcomes. The autonomic dysfunction in diabetes is characterized by increased sympathetic activity and decreased parasympathetic activity, as evidenced by altered heart rate and blood pressure responses in diabetic patients compared to non-diabetic.[6] Heart rate variability, a gold standard for assessing cardiac autonomic dysfunction, is notably reduced in T2DM patients, indicating damage to autonomic nerve fibers and a decrease in both sympathetic and parasympathetic activities, which increases the risk of ventricular arrhythmias and sudden cardiac arrest.[7] Real-time monitoring of HRV in diabetic patients has shown that poorly controlled glucose levels are associated with lower HRV, suggesting that elevated blood sugar levels directly contribute to cardiac autonomic dysfunction.[8]

The distinction between dipping and non-dipping BP patterns is clinically significant, particularly in the context of cardiovascular risks. Dippers exhibited a normal nocturnal decline in BP (>10%), while non-dippers showed a blunted or absent nocturnal decline, maintaining higher BP levels throughout the night. This non-dipping pattern has been associated with increased risks of end-organ damage, cardiovascular incidents, and mortality. Recent investigations have reported a prevalence of non-dipping patterns in 76% of normotensive T2DM patients, underscoring its potential contribution to adverse health outcomes.

Despite the established significance of ABPM in the management of T2DM and HTN, several research gaps remain. Previous studies have explored the link between blood pressure variability and cardiovascular outcomes, with a focus on how diabetes exacerbates these risks. Existing studies often lack comprehensive analysis of the interaction between blood sugar levels and BP variations, particularly in the context of dipping patterns. Moreover, the clinical implications of non-dipping patterns in normotensive T2DM patients remain underexplored.[9] Previous research has been limited by small sample sizes, lack of diversity in patient populations, and inconsistent definitions of dipping and non-dipping patterns.[10]

The present study aimed to address these gaps by evaluating BP variability in a cohort of normotensive T2DM patients, focusing on the prevalence and clinical implications of non-dipping patterns. By employing ABPM, this study sought to elucidate the relationship between BP variations and metabolic parameters, including fasting and postprandial blood glucose levels, lipid profiles, and inflammatory markers. The novelty of this study lies in its focus on normotensive T2DM patients, an underexplored group, and a comprehensive analysis of the relationship between BP variability and metabolic characteristics.

The objectives of this study were to determine the prevalence of non-dipping BP patterns among normotensive T2DM patients; investigate the association between non-dipping patterns and metabolic characteristics, such as BMI, blood glucose levels, lipid profiles, and inflammatory markers; and evaluate the potential need for routine ABPM in normotensive T2DM patients to identify non-dippers and implement targeted interventions. Understanding the prevalence and implications of non-dipping BP patterns in T2DM patients is crucial for improving the clinical management and preventing cardiovascular complications. This study aimed to provide a comprehensive analysis of BP variability, contributing to the existing body of knowledge and informing clinical practices for improved disease management and patient outcomes. By addressing the outlined objectives, this study seeks to advance our understanding of BP patterns in patients with diabetes, ultimately aiding in the development of more effective monitoring and intervention strategies.

Materials and Methods

This observational cross-sectional hospital-based study was conducted in the Department of Medicine. A total of 100 patients with type 2 Diabetes Mellitus (T2DM) who visited the Medicine OPD and Diabetic Clinic between January 2021 and December 2022 were included. A total sum of 58 patients was encompassed in the current investigation. Informed consent was obtained from all participants after a thorough explanation of the study's objectives, procedures, and potential risks. The study adhered to the ethical standards as prescribed in the 1964 helsinki Declaration.

The study included individuals who met the specific criteria for participation. Firstly, participants had to be over 30 years of age. Secondly, a confirmed diagnosis of Type 2 Diabetes Mellitus (T2DM) was required. Additionally, participants were required to be normotensive, with blood pressure measurements consistently below 140/90 mmHg on two separate occasions at least one week apart.[11] These stringent inclusion criteria aimed to ensure that the study focused on individuals with T2DM while excluding those with significant hypertension, thus enabling a more targeted investigation into the intended research objectives.

Individuals were excluded from the study if they met the specific exclusion criteria. Firstly, those currently undergoing antihypertensive treatment or taking medications recognized for their influence on blood pressure were not included. Individuals with documented instances of systemic hypertension, confirmed coronary artery disease, heart failure, or endocrine disorders other than diabetes were excluded.[12] Moreover, participants with established nephropathy characterized by macroalbuminuria exceeding 300 mg/24 h and an albumin-to-creatinine ratio exceeding 34 mg/mmol were not considered. Pregnant individuals were excluded from this study. These exclusion criteria were implemented to ensure that the study sample-maintained focus on the desired parameters, minimizing confounding variables, and enhancing the validity of the findings (Figure 1).

Procedure

A standardized data collection form was used to gather comprehensive clinical and laboratory information from all the enrolled patients. The dataset encompassed various facets, including demographic details and, clinical characteristics, such as diabetes duration, hypothyroidism symptoms, snoring tendencies, smoking history, diabetes treatment particulars, familial occurrences of diabetes and hypertension, Body Mass Index (BMI), waist-to-hip ratio, initial clinic and blood pressure measurements. Furthermore, essential laboratory parameters were recorded, including fasting and postprandial blood glucose, HbA1c, PPBS, FBS, low density lipoprotein (LDL) levels and triglyceride levels (TG).

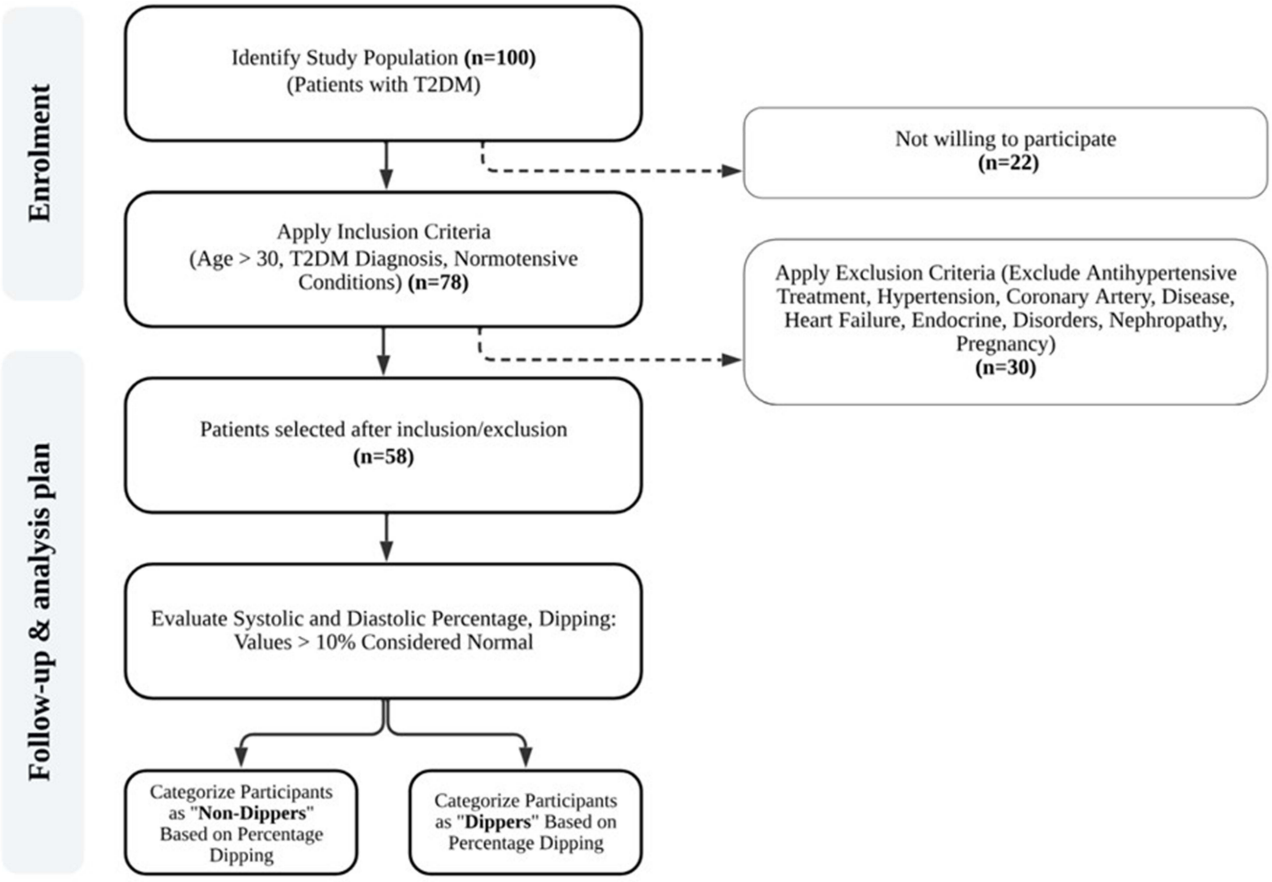

Figure 1 Flow diagram showing patient selection in the study.

Blood Pressure Measurements

The study employed the Sun Tech Oscar 2 ABPMR device, which utilizes oscillometry with step deflation for blood pressure (BP) monitoring. The measurements commenced between 8 am and 10 am, extending over 24 h. To ensure accuracy, three readings were taken using a sphygmomanometer, and three individual measurements were recorded using ABPM device, ensuring a difference of no more than 5 mmHg between the two methods. The Participants were carefully educated on the measurement protocol, with specific instructions provided. They were advised to limit physical activity, abstain from vigorous exertion and caffeine intake, and maintain arm steadiness during cuff inflation.[13]

The Sun Tech Oscar 2 ABPMR device has been validated through several clinical studies and adheres to the protocols established by both the European Society of Hypertension and the Association for the Advancement of Medical Instrumentation[14,15] (Goodwin et al, 2007)(Roth et al, 2023). These validation studies have demonstrated the device's high reliability and accuracy in capturing 24-hour ambulatory blood pressure measurements[16] (O'Brien et al, 2002). In the present study, the device was regularly calibrated as per manufacturer recommendations to ensure consistent and accurate BP readings.

During each of the three measurement intervals (24-hour, daytime, and nighttime), the averages for systolic and diastolic blood pressure values were computed. Furthermore, the study evaluated systolic and diastolic dipping percentages, where values exceeding 10% were considered within the normal range. Categorization of "dippers" was established based on the degree of percentage dipping. Individuals were classified as "dippers" if both systolic and diastolic blood pressure exhibited reductions of at least 10%.[17,18] This categorization allowed for the identification of participants who experienced substantial reductions in blood pressure during specific time periods. Throughout the entire 24-hour period, the ABPM recorder was consistently attached to each participant, gathering average measurements of vitals.

Statistical Analysis

The collected data were coded and entered into an excel software (Microsoft office Excel 2010) database. Data were analysed using the Statistical Package for Social Sciences (version 16.0; SPSS, Inc., Chicago, IL, USA). Descriptive statistics, including mean and standard deviation, were calculated for each continuous outcome measure. Continuous variables were compared using Student's *t*-test. For variables presented as medians with interquartile ranges (eg, lipoprotein (a), ferritin, mg/dL), the Mann–Whitney *U*-test was used. Categorical variables are expressed as numbers and percentages and compared across groups using Pearson's chi-square test for independence of the characteristics of categorical variables. The level of significance was set at $p < 0.05$.

Results

Table 1 presents the baseline clinical characteristics in both the non-dipper (n=45) and dipper (n=13) groups. Age, gender, diabetes duration, BMI, and waist-to-hip ratio were measured. No significant differences were observed in age, gender distribution, diabetes duration, and BMI or waist-to-hip ratio between groups. Blood pressure patterns seem influenced by factors beyond those measured, implying that other variables might play a more significant role in differentiating the two groups.

Table 1 Comparison of Clinical Characteristics Between Non Dipper and Dipper Groups

Characteristic	Non-Dipper (n=45)	Dipper (n=13)	p-value
Age (years)	45.5±5.8	46.4±8.1	0.65
Gender (Males/ female)	27 (60.0%) 18 (40.0%)	9 (69.2%) 4 (30.8%)	0.55
Duration of DM, years	4.1±2.8	3.4±3.3	0.44
BMI (kg/m²)	24.3±3.7	22.5±2.1	0.10
W-H ratio	0.89±0.12	0.88±0.32	0.86

Abbreviations: BMI, Body mass index; W-H, Waist to Hip; DM, Diabetes Mellitus; HTN, Hypertension.

Table 2 shows the comparison between non-dipper and dipper groups. It has been shown that the HbA1c levels were not significantly differed between the group (9, p = 0.63); However, the dipper group showed significantly lower PPBS (p = 0.02) and higher FBS (p = 0.04). Lipid profile variations included higher HDL cholesterol (p = 0.02) but elevated LDL cholesterol (p = 0.01) in the dipper group. TG were lower in the dipper group (p = 0.01), and Apo B exhibited significant differences (p < 0.001). Inflammatory markers showed lower homocysteine (p = 0.04) and CRP (p < 0.001) levels in the dipper group.

Table 3 compares of blood pressure (BP) measurements and disease history between the non-dipper and dipper groups. Whereas the SBP and DBP measurements at a single point in time did not differ significantly between the groups (p = 0.51 and p = 0.68, respectively), the 24-hour average SBP and average nighttime SBP were significantly higher in the dipper group (p = 0.00 and p < 0.001, respectively). Conversely, the average nighttime DBP was lower in the dipper group (p = 0.02). The prevalence of hypertension approached significance, with a trend towards a higher percentage in the non-dipper group (88.9% vs 69.2%, p = 0.08). Additionally, family history of hypertension showed a similar trend (22.2% vs 7.7%, p = 0.24).

Table 4 shows that the comparison of medication usage between non-dipper and dipper groups No significant differences in the number of antihypertensive drugs taken, with similar proportions in both groups for none. Notably, there were no instances of AT1-receptor blockers used in either group. The prevalence of specific antihypertensive medications, including beta blockers, insulin therapy, diuretics, ACE inhibitors, calcium channel blockers (CCB), alpha1-antagonists, alpha2-agonists, oral antidiabetic drugs, and statins, showed no significant differences between non-dipper and dipper groups (all p > 0.05).

Table 5 presents a multivariate analysis with the non-dipper group as the reference category against the dipper group. Elevated odds ratios indicate a heightened probability of belonging to the dipper group. Notably, concerning metabolic characteristics, increased levels of PPBS, FBS, HDL cholesterol, LDL cholesterol, TG, ApoB, homocysteine, and CRP

Table 2 Comparison of Laboratory Results Between Non Dipper and Dipper Groups

Laboratory parameters	Non-Dipper (n=45)	Dipper (n=13)	p-value
Metabolic characteristics			
HBA1c (%)	8.2 ±2.1	7.9±1.5	0.63
PPBS, mg/dl	333.0 ±104	259.0 ±98	0.02
FBS, mg/dl	176.0 ±23	195.0 ±44	0.04
Total cholesterol, mmol/L	5.8 ± 1.3	5.3 ± 0.8	0.19
HDL cholesterol, mmol/L	1.1 ± 0.3	1.3 ± 0.2	0.02
LDL cholesterol, mmol/L	4.4 ± 0.4	4.8 ± 0.6	0.01
TG, mmol/L	1.8 ± 0.5	1.4 ± 0.3	0.01
Lipoprotein (a), nmol/L	20 (15–70)	23 (17–62)	0.56
Apo A1, mg/dL µmol/L	48 ± 8	49 ± 6	0.67
Apo B, µmol/L	2.3 ± 0.3	2.0 ± 0.4	< 0.001
Inflammatory markers			
Homocysteine, µmol/L	10.2 ± 2.1	8.8 ± 2.2	0.04
Urate, mg/dL	5.3 ± 1.1	5.1 ± 0.9	0.55
Fibrinogen, mg/dL	365 ± 56	380 ± 61	
Ferritin, mg/dL	72 (60–110)	100 (35–220)	0.64
ESR, mm/2 h	30 ± 11	28 ± 10	0.40
CRP, mg/dL	0.5 ± 0.2	0.3 ± 0.1	<0.001

Notes: Data are presented as mean± standard deviation and median (interquartile range). Differences were tested using Student's *t*-test and, Mann–Whitney *U*-test.

Abbreviations: HbA1c, glycated haemoglobin; PPBS, Postprandial blood sugar; FBS, Fasting blood sugar; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, Triglycerides, ACE, angiotensin-converting enzyme; Apo A-1, apolipoprotein A-1; ApoB, apolipoprotein B; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate.

Table 3 Comparison of BP Measurements and History of Disease Between Non Dipper and Dipper Groups

Measurement of BP	Non-Dipper (n=45)	Dipper (n=13)	p-value
SBP (mmHg)	114 ± 9.8	116 ± 9.6	0.51
DBP (mmHg)	78.1 ± 7.6	79.3 ± 8.8	0.68
24 h Average SBP (mmHg)	125.3 ± 17.2	139.8 ± 10.7	0.00
24 h Average DBP (mmHg)	86.1 ± 11.6	87.1 ± 13.1	0.79
Average daytime SBP, mmHg	135.5 ± 10.2	134.4 ± 12.0	0.74
Average daytime DBP, mmHg	78.2 ± 5.6	79.2 ± 6.1	0.58
Average nighttime SBP, mmHg	129.5 ± 11.1	116.0 ± 9.8	<0.001
Average nighttime DBP, mmHg	72.5 ± 7.5	67.0 ± 7.3	0.02
Hypertension, n (%)	40 (88.9)	9 (69.2)	0.08
Controlled hypertension, n (%)	4 (8.9)	1 (7.7)	0.89
Uncontrolled hypertension, n (%)	36 (80.0)	8 (61.5)	0.17
Family history of HTN, n (%)	10 (22.2)	1 (7.7)	0.24
Family history of DM, n (%)	25 (55.6)	5 (38.5)	0.28
Active smokers, n (%)	14 (31.1)	4 (30.8)	0.98
Ex-smokers, n (%)	9 (20.0)	3 (23.1)	0.81

Notes: Data are presented as mean± standard deviation and number (percentage). Differences were tested using Student's *t*-test and Chi-square test. SBP: Systolic blood pressure, DBP: Diastolic blood pressure.

Table 4 Comparison of Medication Taken by Non-Dipper and Dipper Groups

Number of antihypertensive drugs	Non-Dipper (n=45)	Dipper (n=13)	p value
None, n (%)	14(31.1)	6(46.2)	0.32
One, n (%)	14(31.1)	3(23.1	0.58
Two, n (%)	12(26.7)	2(15.4)	0.40
More than two, n (%)	6(13.3)	2(15.4)	0.80
AT1-receptor blockers, n (%)	0(0.0)	0(0.0)	-
Beta blockers, n (%)	2(4.4)	1(7.7)	0.64
Insulin therapy, n (%)	15(33.3)	4(30.8)	0.86
Diuretics, n (%)	7(15.6)	1(7.7)	0.47
ACE inhibitors, n (%)	22(48.9)	5(38.5)	0.50
Calcium channel blocker (CCB), n (%)	9(20.0)	2(15.4)	0.71
Alpha1-antagonists, n (%)	4(8.9)	1(7.7)	0.89
Alpha2-agonists, n (%)	1(2.2)	0(0.0)	-
Oral antidiabetic drugs, n (%)	18(40.0)	6(46.2)	0.69
Statins, n (%)	4(8.9)	1(7.7)	0.89

Table 5 Multivariate Analysis Results

Variables	Beta (B)	Standard error (SE)	P value	Odds ratio	95% CI for Odds ratio	
					Lower	Upper
PPBS mg/dl	0.99	0.99	1.07	1.99	1.98	2.00
FBS mg/dl	0.11	0.11	0.19	1.11	1.10	1.12
HDL cholesterol, mmol/L	0.23	0.03	0.00	1.26	1.20	1.32
LDL cholesterol, mmol/L	0.65	0.15	0.04	1.92	1.04	3.53
TG, mmol/L	0.42	0.08	0.01	1.52	1.23	1.87
Apo B, μmol/L	0.78	0.26	0.00	2.20	1.43	3.38
Homocysteine, μmol/L	0.16	0.06	0.01	1.18	1.04	1.33

(*Continued*)

Table 5 (Continued).

Variables	Beta (B)	Standard error (SE)	P value	Odds ratio	95% CI for Odds ratio	
					Lower	Upper
CRP, mg/dL	0.74	0.12	0.00	2.10	1.73	2.55
24-hour Average SBP (mmHg)	0.54	0.40	0.30	0.30	0.76	1.25
Average night time SBP, (mmHg)	0.64	0.19	0.00	1.90	1.33	2.71
Average night time DBP, mmHg	0.51	0.09	0.00	1.67	1.37	2.05
Hypertension, n (%)	0.12	0.06	0.04	1.13	1.00	1.28

were associated with an increased likelihood of being dippers. Specifically, the odds of being a dipper were approximately twice as high for each unit increase in PPBS and FBS, 2.202 times higher for Apo B, and 2.102 times higher for CRP. Additionally, higher 24-hour average SBP and nighttime SBP were associated with reduced odds of being a dipper, with odds ratios of 0.309. Conversely, elevated nighttime DBP and hypertension were associated with increased odds of being a dipper, with odds ratios of 1.678 and 1.133, respectively.

Discussion

The present study explored the relationship between diurnal blood pressure variation and glucose levels in patients with type 2 diabetes and established a foundation for understanding their interdependence.[19] Additionally, studies on cardiovascular autonomic neuropathy in diabetes have provided insights into the physiological underpinnings of blood pressure variations.[20] Furthermore, the impact of obesity on 24-hour ambulatory blood pressure and hypertension revealed the influence of metabolic factors.[21] The role of oxidative stress in diabetic complications further deepens our understanding of these mechanisms.[22] However, variations in prevalence rates suggest the influence of diverse patient populations and other potential confounding factors.[23]

The clinical outcomes of this study were similar to those of earlier trials, with over 77% of the individuals evaluated for ABPM exhibiting a non-dipping pattern and only one-fourth showing a dipping pattern. A previous study reported a 58% incidence of non-dipping in normotensive middle-aged T2DM patients. There were no significant differences in age, sex distribution, diabetes duration, or waist-to-hip ratio between the dipping and non-dipping groups, suggesting that other unmeasured factors might influence blood pressure patterns more distinctly. Additionally, the mean duration of diabetes at presentation did not differ significantly between groups. However, higher BMI showed a stronger association with the non-dipping pattern, which is consistent with previous findings. Similarly, a study reported a 71.4% incidence of nondipping BP in obese patients.[21] Non-dippers demonstrated a marginally higher incidence of familial diabetes and hypertension, suggesting a potential genetic predisposition to these conditions. Few studies are in line with the present study.[19,24,25]

In our study, the mean ages of dippers and non-dippers were similar. Notably, non-dippers exhibited higher weight and BMI than dippers did. Coincidentally, Karaagac et al reported similar findings.[23] Laboratory results of the present study and their potential implications in diabetes and cardiovascular health. The lack of significant differences in HbA1c, LDL-cholesterol, and triglyceride levels between the non-dipper and dipper groups highlights the complexity of this relationship. However, contrasting trends in postprandial and fasting blood sugar levels were noteworthy. The dipper group's improved post-meal glucose control and the non-dipper group's superior fasting glucose control suggest potential disparities in diabetes management and metabolic health between the two groups. A similar study reported that the mean HbA1c level was lower in non-dippers. In contrast, the mean TG levels in the non-dippers and dippers were similar. The mean LDL levels in non-dippers were higher. Furthermore, no statistical differences were reported in a study on TG, LDL, and HbA1c levels between the two groups.[26] Our findings are also in agreement with the study by Akçay et al, who reported that dippers with hypertension and control participants' HbA1c levels did not differ significantly. The HbA1c values of the non-dipper patients were substantially higher than those of controls. The difference was not statistically significant, despite the fact that non-dippers tended to have higher HbA1c levels than dippers.[27]

In the present study, no significant differences were found in daytime systolic or diastolic BP. However, the dipper group had a significantly higher 24-hour average systolic BP and showed increased dipping percentages for both systolic and diastolic BP during sleep. This indicates a more pronounced nighttime BP drop in the dipper group, potentially affecting cardiovascular health. Non-dippers had a slightly higher prevalence of family history of diabetes and hypertension. These findings emphasize the importance of nocturnal BP variation in distinguishing between groups. In concordance with the present study, Neeradi et al also found that the SBP and DBP dipping percentages in the non-dipper group were lower than those in the dipper group.[23]

Draman et al's investigation parallels our study, revealing a substantial 55% prevalence of non-dipping patterns among type 2 diabetes patients, underscoring the notable occurrence of abnormal circadian blood pressure (BP) cycles.[28]

Consistent with our results, Gunawan et al highlighted aberrant circadian BP patterns and reported that 23% of their cohort displayed non-dipping or reverse-dipping rhythms. Among these, 16% exhibited reverse-dipping patterns and 84% exhibited non-dipping patterns.[29] Interestingly, Nakano et al's study resonated with our findings, suggesting a higher likelihood of non-dipping status among older individuals with diabetes.[30] Moreover, Lindsay et al revealed an association between nocturnal non-dipping and nephropathy in patients with type 2 diabetes, supported by statistically significant links between non-dipping and elevated urinary albumin excretion.[31] This echoes the findings of Björklund et al, who reported a noteworthy association between glycemic control and non-dipping, with non-dippers displaying improved glycaemic levels.[32] In essence, our study showed a relationship between type 2 diabetes, circadian BP patterns, and associated health implications. Multivariate analysis in the present study revealed the lack of predictive significance of the 24-hour average systolic blood pressure. Postprandial blood sugar (PPBS) and fasting blood sugar (FBS) levels exhibited substantial associations. In finding supported A multivariate analysis conducted by Neeradi et al revealed that fasting blood glucose and HbA1c levels were not statistically significant predictors of non-dipping patterns.[23] In a recent study by El Shaaer (2023), multivariate analysis revealed that age and HbA1c levels emerged as independent predictors of BP dipping.[33] Spallone et al highlighted the influence of nighttime sleep and variations in daily activity on blood pressure monitoring. Notably, their study employed flexible day and night periods based on individual sleep schedules, thus contributing to consistent recording circumstances.[20]

This study had some limitations that need to be addressed. We acknowledge the concern regarding the small sample size, which is a limitation of this study and may affect the generalizability of the findings. Additionally, the lack of a diverse patient population and the cross-sectional design limits the ability to establish causality. Future studies with larger cohorts and longitudinal designs are required to validate these findings.

Conclusion

The findings of this study emphasize the importance of monitoring nocturnal BP variation, as the dipper group exhibited a more pronounced night-time BP drop. The application of this study lies in its potential to advance cardiovascular risk management for diabetic patients, particularly by underscoring the need for routine ambulatory blood pressure monitoring (ABPM) in normotensive individuals. This study paves the way for more targeted interventions in this underexplored patient population, contributing to improved clinical practices in diabetes management and preventing future complications related to blood pressure variability.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically

reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no conflicts of interest in this work.

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