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ACH ANNALS OF CLINICAL HYPERTENSION
ISSN 2639-6629

Observational Study

Differentiation of the Non-dipping Blood Pressure Phenotype in Obstructive Sleep Apnea: An Observational Study

Matilde Valencia-Flores[1,2]*, Victoria Santiago-Ayala[2], Margarita Fernández López[3], Jorge Oseguera Moguel[3], Gerardo Payró Ramirez[3], Montserrat Reséndiz-Garcia[2], Montserrat Memetla-Argumedo[2], Gabriela Gaytán-Cervantes[2], Ramón Morales-Navarro[2], Carlos A. Aguilar-Salinas[4-6] and Donald L. Bliwise[7]

[1]Research and Graduate Studies Division, School of Psychology, UNAM, México City, México
[2]Sleep Laboratory, Department of Neurology and Psychiatry, INCMNSZ, México City, México
[3]Department of Cardiology, INCMNSZ, México City, México
[4]Research Unit in Metabolic Diseases, INCMNSZ, México City, México
[5]Direction of Research, INCMNSZ, México City, México
[6]School of Medicine and Health Sciences, Tecnológico de Monterrey, México City, México
[7]Neurology Department, Emory University School of Medicine, Atlanta, GA, USA

More Information

***Address for correspondence:**
Matilde Valencia-Flores, Ph.D, Research and Graduate Studies Division, School of Psychology, UNAM, México City, México,
Email: valflor@unam.mx;
matilde.valenciaf@incmnsz.mx

https://orcid.org/0000-0003-1608-9129

Submitted: May 08, 2025
Approved: May 14, 2025
Published: May 15, 2025

How to cite this article: Valencia-Flores M, Santiago-Ayala V, López MF, Mogue JO, Ramirez GP, Reséndiz-Garcia M, et al. Differentiation of the Non-dipping Blood Pressure Phenotype in Obstructive Sleep Apnea: An Observational Study. Ann Clin Hypertens. 2025; 9(1): 001-008. Available from: https://dx.doi.org/10.29328/journal.ach.1001037

Keywords: Obstructive sleep apnea; Insomnia; Non-dipping blood pressure; Sleep quality; Running head; Non-dipping BP in OSA patients with poor sleep quality

Abstract

Background: Absence of nocturnal decrease in Blood Pressure (BP) ("non-dipping") has been shown to be a strong and independent predictor of cardiovascular events, target organ damage, cardiovascular sequela and cardiovascular mortality. Obstructive Sleep Apnea (OSA) has been associated with non-dipping with an estimated prevalence of approximately 50%, but factors associated with non-dipping in OSA patients remain poorly understood. In this study, we examined clinically relevant variables associated with non-dipping in OSA.

Methods: Patients (n = 35) undergoing overnight valuation for OSA, laboratory-based polysomnography, structured clinical interviews, and comprehensive metabolic and anthropometric evaluations, and ambulatory BP monitoring for 24 hours. Patients were classified into a) dipping BP group or b) non-dipping BP group, based on (a) a nocturnal systolic BP decrease of 10% - 20% or (b) a systolic BP decrease of < 10%.

Results: Patients had moderate and severe OSA (AHI = 34.8 ± 29.1), and 42.9% demonstrated a non-dipping BP pattern. The severity of OSA measures did not differ between dipping group and non-dipping group. However, Wake after Sleep Onset (WASO) and chronicity of insomnia predicts non-dipping BP independent of demographics, sleep stages, anthropometrics, metabolic measures, or arterial stiffness.

Conclusion: These findings contribute to a better understanding of the cardiovascular impacts of OSA and indicate that sleep quality should be incorporated into clinical assessments and management of OSA patients.

Abbreviations

AASM: American Academy of Sleep Medicine; ABPM: Ambulatory Blood Pressure Measurement; AHI: Apnea and Hypopnea Index; ASI: Arterial Stiffness Index; AUC: Area Under the Curve; BMI: Body Mass Index; BP: Blood Pressure; BPV: Blood Pressure Variability; CAP: College of American Pathologists; CDC: Center for Disease Control; CPAP: Continuous Positive Airway Pressure; CV: Cardiovascular; ECG: Electrocardiogram; GERD: Gastroesophageal Reflux Disease; HDL: High-Density Lipoprotein; HPLC: High Performance Liquid Chromatography; INCMNSZ: National Institute of Medical Science and Nutrition Salvador Zubirán; LDL: Low-Density Lipoprotein; MSI: Morning Surge Index; NGSP: National Glycohemoglobin Standardization Program; ODI: Oxygen Desaturation Index; OSA: Obstructive Sleep Apnea; PLMS: Periodic Limb Movements of Sleep; PLMSI: Periodic Limb Movements of Sleep-Index; PSG: Polysomnographic;

PUD: Peptic Ulcer Disease; REM: Rapid Eye Movement; ROC: Receiver Operating Characteristic; SD: Standard Deviation; SpO_2: Blood Oxygen Saturation Percentage; WASO: Wake after Sleep Onset

Introduction

Blood Pressure (BP) follows a circadian rhythm, decreasing (10% - 20%) during sleep, and this decrease has been associated with cardiovascular health [1,2]. In contrast, a lack of BP decrease (non-dipping) [3,4] is an independent predictor of cardiovascular events, target organ damage, cardiovascular sequelae and cardiovascular mortality [5-11]. BP non-dipping may be modulated by the sympathetic nervous system [12], disturbed baroreflex sensitivity [13], or increased salt sensitivity [14], as well as metabolic alterations such as Glycemic imbalance and type 2 diabetes mellitus [15-17].

In addition to these conditions, there is substantial evidence in both cross-sectional and longitudinal studies that respiratory alterations during sleep, such as Obstructive Sleep Apnea (OSA), are associated with increased frequency of non-dipping of systolic BP in a dose–dependent manner [18-21]. For example, a recent study [22] characterized sleep parameters using Polysomnography (PSG) associated with alterations in the circadian blood pressure pattern revealed that respiratory parameters such as the apnea/hypopnea index (AHI), oxygen saturation level, and respiratory arousal index contributed to the non-dipping of BP.

In this study, we expanded the range of possible variables contributing to non-dipping in OSA patients by studying OSA patients presenting at a tertiary care hospital in Mexico City.

Methods

Participants

Consecutive patients (n = 67) referred to the National Institute of Medical Sciences and Nutrition Salvador Zubirán (INCMNSZ) Sleep Laboratory for suspected breathing disorders during sleep were invited to participate in the study. Those with other comorbidities that could affect the cardiovascular system or sleep characteristics (psychiatric, neurological disorders, and current use of psychotropics) were excluded (Figure 1), resulting in 35 eligible participants.

Study design

We conducted a cross-sectional, observational study comparing OSA patients with a dipping BP pattern with those with a non-dipping BP pattern. Dipping was defined as a nocturnal systolic BP decrease (10% - 20%) during sleep, whereas non-dipping was defined as a nocturnal BP decrease < 10%. Over a 10-month period (June 2022–March 2023), all consecutive patients who were referred to the Sleep Laboratory of INCMNSZ were invited to participate in the study. The study was approved by the INCMNSZ Institutional Committee for Biomedical Research Involving Humans (protocol # 2338); written informed consent was obtained from all participants. To be included in the study, patients were required to complete overnight PSG and demonstrate an AHI ≥ 5 per hour, as well as willingness to undergo laboratory tests and 24-hour ambulatory BP monitoring. To determine the sample size and statistical power, we considered two-tailed type I error (α) = 0.05, with a power of 85% (type B error = 0.15), and assumed a prevalence of non-dipping of 59%. This was projected to a sample size of n = 50; however, we allowed for 15 cases with incomplete data, resulting in a targeted sample of n = 65. Sixty-seven cases were approached, but after eliminating cases with inadequate data collection or confounding comorbidities (Figure 1), the final sample was n = 35.

Anthropometry, health-related variables and habits questionnaire

Body weight was measured to the nearest 0.1 kg, and height was measured to the nearest 0.1 cm using a Seca 284 stadimeter with a 1 mm gradation. Waist circumference was evaluated via an inelastic Seca 201 tape with 0.1 cm precision placed directly over the skin at the midpoint between the ribcage and the iliac crest with the tape parallel to the floor and standing with their feet together with weight evenly distributed, holding the arms in a relaxed position at the side, and breathing normally. Waist and hip circumferences were taken to derive the waist–hip ratio.

Body Mass Index (BMI) was calculated as weight in kg divided by the squared product of height in meters. All anthropometric measurements were performed on the day of

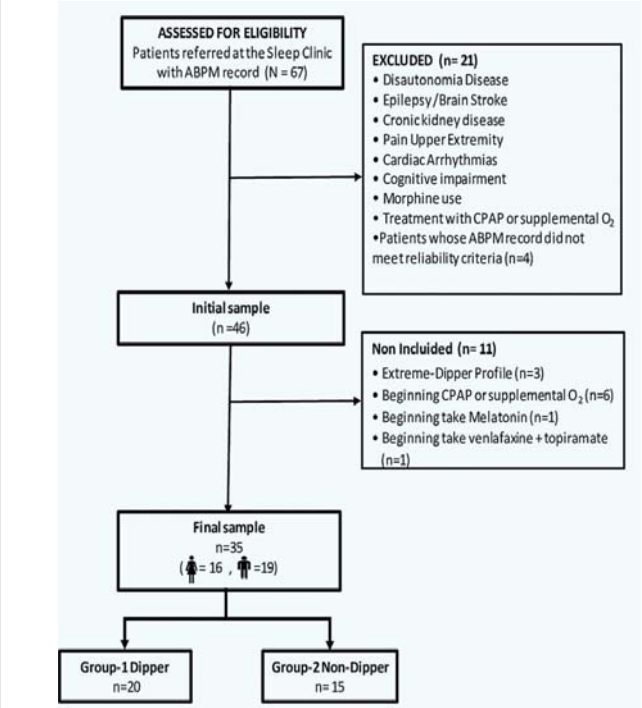


Figure 1: Participant recruitment and selection flowchart.

the sleep studies by a trained technician. The questionnaire collected data on demographics, drinking behavior, and smoking habits [Smoking Index (number of cigarettes per day by number of years)/20 cigarettes)] has been previously described [23]. The questionnaires were administered prior to PSG.

Ambulatory BP Measurement (ABPM)

ABPM was performed 36 hours before Polysomnography (PSG) to prevent the disruptive influence of cuff inflation on sleep. BP monitoring was performed with the Spacelabs healthcare device (OnTrak 90227 monitor, Snoqualmie, WA, USA), which measures blood pressure and heart rate over 24-hour periods, providing the following parameters: blood pressure variability (calculated as the Standard Deviation (SD) of all BP observations over the measurement period); estimation of mean blood pressure by day, night and over 24 h; and drop in blood pressure overnight measured as a ratio of nocturnal mean BP to day mean BP expressed as a percentage. We also examined the morning surge index (MSI), which was calculated as the mean systolic BP during the 2 hours after awakening minus the mean systolic BP during the 1 hour that included the lowest sleep BP. MSI has been associated with adverse cardiovascular events [24,25], and is a relevant measure of changes in BP. We also derived the Arterial Stiffness Index (AASI), which was calculated as 1 minus the regression slope of the diastolic versus the systolic pressure over the 24-hour BP recordings. The AASI has been proposed as a marker of arterial stiffness, as it is correlated with markers of preclinical target organ damage and CV outcomes, especially stroke [26,27].

We followed the technical recommendations of the position statement on ABPM by the Spanish Society of Hypertension [28], which is based on the European Society of Hypertension Working Group [29]. We considered recordings acceptable with a minimum of one reading per hour and to have at least 70% valid measurements obtained at least every 30 minutes during the nighttime sleep period and every 15 minutes during the daytime. ABPM recordings were independently reviewed by a cardiologist specializing in hypertension. We used sleep diaries provided to each patient during ABPM to determine the start and end of the sleep period during the 24 hours in which they wore the unit.

Polysomnography (PSG)

We recorded one night of laboratory-based PSG using standard techniques. Recordings began at each subject's usual bedtime and ended at their typical wake-up time in the morning. Quantitative evaluations of sleep stages were generated visually by an experienced technologist via the American Academy of Sleep Medicine (AASM) rules [30]. All the recordings were generated on a NicVue system (version 3.0.6, 2013, Natus Medical Incorporated, Middleton, WI, USA) and consisted of simultaneous monitoring of surface electroencephalogram, electro-oculogram, electromyograms of the mentalis and bilateral anterior tibialis muscles, and an Electrocardiogram (ECG) (Lead II). Respiratory movements were monitored via a plethysmography belt. Oral/nasal airflow was monitored with a four-bead thermistor system and a pressure transducer airflow sensor. Oxygen saturation (SpO_2) was recorded with an ear pulse oximeter (Capnocheck Sleep 9004-001, Smith Medical PM, Inc., Waukesha, WI, USA).

The number of abnormal breathing events per hour of sleep was quantified as the AHI. Obstructive apneas were defined by a ≥ 90% drop in peak signal excursion of pre-event baseline using the oral/nasal thermal sensor for a duration ≥ 10 s with continued inspiratory effort. Central apneas were scored if the apnea criteria were met but with no inspiratory effort throughout the entire period of absent airflow. Mixed apneas were scored if the apnea criteria were met, and the event was associated with concomitant absent inspiratory effort in the initial portion of the event, followed by resumption of inspiratory effort in the second portion of the event. Hypopneas were scored if the nasal pressure excursion signal dropped by 30% of baseline for a minimum duration of at least 10 s accompanied by a ≥ 3% drop in oxygen saturation (SpO2) from the pre-event baseline. We defined the presence of sleep apnea as an AHI ≥ 5 events per hour, although the majority of the patients studied had moderate or severe sleep apnea (AHI > 30) (see Results). The Oxygen Desaturation Index (ODI) was defined as the number of drops in SpO_2 ≥ 3% per hour of sleep. Periodic Limb Movements of Sleep (PLMS) were scored on the basis of AASM rules [30] and were quantified as the number of leg movements per hour to yield a PLMS index (PLMSI).

Biochemical and metabolic measurements

Following the night of PSG, patients underwent a morning fasting venous blood draw for serum glucose and lipid panel testing. The values of glycosylated hemoglobin were determined via HPLC on a Bio-Rad model D-100 platform, with accreditation by NGSP level 1 and CAP. The plasma glucose concentration was measured with an automated glucose analyzer (Yellow Springs Instruments, Yellow Springs, OH, USA), and lipid profiling was carried out using an enzymatic method with a Beckman Coulter AU 5800 platform accredited by the CAP and certified by the CDC as of 2021. The diagnosis of diabetes was made by an internist or an endocrinologist on the basis of the American Diabetes Association Guidelines, 2019 [31].

Statistical analysis

Data were analyzed via SPSS version 21.0 software (IBM Corporation). For continuous data, the Shapiro–Wilk test was used to determine a normal distribution, assuming normality when $p > 0.05$. For these variables, we used parametric tests. Non-normally distributed data were analyzed using nonparametric methods. Categorical data are presented as frequencies and proportions. Missing values (< 20%) were imputed using median substitution for variables with fewer than 20% missing cases.

We employed multivariate logistic regression models to examine which variables best predicted blood pressure status, assigning non-dipping status as 1 and dipping status as 0. All hypothesis testing was 2tailed with an alpha level of 0.05. We used ROC analysis to further clarify the accuracy of the predictive variables and to determine the cutoff values for the presence or absence of a dipping BP pattern.

Results

Forty-three percent of the samples (n = 15) exhibited a nocturnal blood pressure reduction of less than 10% and were therefore classified as non-dipping. There were no significant differences in age, BMI, other measures of adiposity or smoking history. The non-dipping group presented elevated glycosylated hemoglobin and reduced triglyceride levels (see Table 1). Chronic insomnia was more common among non-dippers (defined as a sleep complaint of poor sleep for ≥ 2 years) (Table 1).

Medication use did not differ between the two groups (Table 2). One patient in the dipping group and two in the non-dipping group were taking three or more antihypertensive drugs, including a diuretic.

Table 3 shows in detail the multiple BP measures derived from the 24-hour monitoring. By definition, there were statistically significant group differences in the decrease in nocturnal systolic blood pressure and in the decrease in nocturnal diastolic blood pressure. Compared with dippers, non-dippers presented a lower MSI and higher AASI.

There were no significant differences between groups for measures of OSA severity. However, the non-dippers presented a substantially less consolidated sleep pattern, with an increase in wakefulness after sleep onset (WASO), which was greater than double the value of the dippers (Table 4). Logistic regressions (Table 5) incorporating triglycerides (Model 1) or glycosylated hemoglobin (Model 2), as well as age, BMI, (AASI), and sleep disruption variables (time awake after sleep onset, chronicity of reported insomnia), indicated that the latter variables were the most salient predictors of non-dipping status (R^2 Nagelkerke = 0.691). Using nonparametric ROC analysis, we evaluated the area under the curve (AUC) for two predictive variables: insomnia lasting ≥ 2 years and WASO. The AUC for reported insomnia years was not significant (AUC = 0.667 ± 0.096, 95% CI: 0.479–0.854,

Table 1: Anthropometric and Clinical Variables by Dipping Status (N=35).

Variables	Dipping n = 20	Non-Dipping n = 15	p - value
Age years (*)	48.6(13.0)	55.0(12.1)	0.149
Sex (% women)	40.0	53.3	0.433
BMI kg/m^2	33(26.8-61.2)	33.6(26.1-54.9)	0.884
Neck circumference cm (*)	42.1(5.2)	41.2(4.5)	0.587
Waist circumference cm	106.5(85-157)	108.0(83-162)	0.807
Hip circumference cm	110(98-160)	112(95-152)	0.884
Waist/Hip ratio (*)	0.96(0.07)	0.98(0.09)	0.417
Smoking Index	1.13(0-30)	0(0-40)	0.591
Nocturia (number of nightly voids)	1.0(0-3)	2(0-7)	0.260
Reported insomnia ≥2 y [a]	20%	53.3%	0.040
Fasting glucose mg/dl	91(76-200)	100(63-119)	0.994
Hemoglobin A1c %	5.8(4.9-8)	6(5.3-9.2)	0.038
Total cholesterol mg/dl (*)	166.2(33.0)	157.0(26.7)	0.382
HDL cholesterol mg/dl (*)	43.7(7.6)	44.3(12.0)	0.855
LDL cholesterol mg/dl (*)	97.7(28.6)	90.4(23.5)	0.430
Triglycerides mg/dl	140(78-265)	109(75-431)	0.043
Dyslipidemia, n (%)	8(40)	10(66.7)	0.118
DM2, n (%)	5(25)	7(46.7)	0.181
Hypertension, n (%)	14(70)	13(86.7)	0.245

Data represent median values, (Min-Max), and p - value for Wilcoxon–Mann–Whitney U two sample test. (*) Data represent mean values, (SD), and p - value for independent samples Student´s t - Test. BMI: Body Mass Index; HDL: High-density Lipoprotein LDL: Low-density Lipoprotein; a Chi-Square=4.227.

Table 2: Medications by Dipping Status.

Medication	Dipping n = 20	Non-Dipping n = 15
No Medication	2	1
Antihypertensive Thiazide or diuretics (unique or combined with antihypertensive)	12 4	9 5
Antidiabetic Drugs	8	10
Dyslipidemia Medication	5	7
GERD or PUD Medication (omeprazole, antacid magaldrate, trimebutine)	0	5
Antirheumatic drugs (metotrexate, ibuprofen, allopurinol)	4	3
Vitamin and Natural Supplements	8	5

GERD: Gastroesophageal Reflux Disease; PUD: Peptic Ulcer Disease. No statistically significant difference between groups for any category of medication; all chi-squares were non-significant.

Table 3: Ambulatory Blood Pressure Parameters and Dipping Status (N = 35).

Variables	Dipping (≥10% and ≤20%) n = 20	Non-Dipping (<10%) n = 15	p - value
24-h mean systolic blood pressure (mmHg)	123.7	121.9	0.728
24-h mean diastolic blood pressure (mmHg)	76.3	72.7	0.274
24-h mean heart rate (beats/min)	75.4	80.5	0.199
Daytime mean systolic blood pressure (mmHg)	128.6	123.5	0.328
Daytime mean diastolic blood pressure (mmHg)	79.5	74.1	0.123
Daytime mean heart rate (beats/min)	78.6	84.5	0.142
Night-time mean systolic blood pressure (mmHg)	112.4	118.7	0.221
Night-time mean diastolic blood pressure (mmHg)	67.6	69.4	0.568
Night-time mean heart rate (beats/min)	67.1	72.8	0.165
Decrease in nocturnal systolic blood pressure %	13.7	6.6	0.0001[a]
Decrease in nocturnal diastolic blood pressure %	15.5	7.0	0.0001[b]
Morning surge index (MSI) mmHg	16.1	8.7	0.032[c]
Ambulatory arterial stiffness index (AASI), units	0.44	0.52	0.026[d]
Blood pressure variability (BPV) mmHg	13.1	11.6	0.209

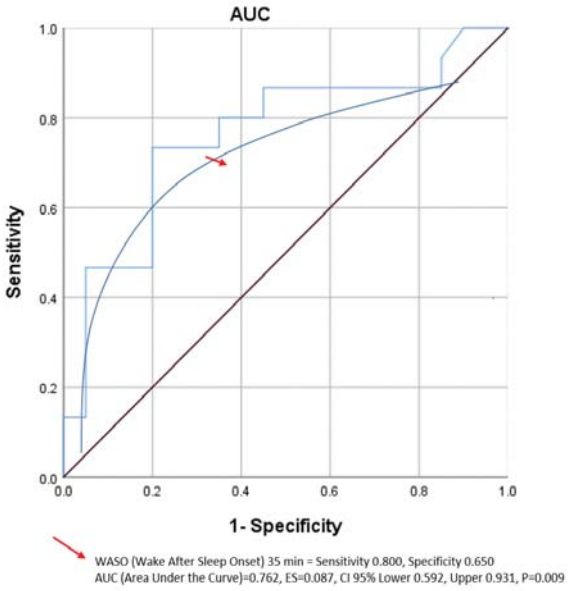
Data represent mean value, and P-value for independent samples Student´s t - Test. a t - Test= 5.448; b t - Test= 5.64; c t -Test= 2.241; d t - Test=-2.324.

Table 4: Polysomnographic Variables by Dipping Status (N = 35).

Variables	Dipping *n* = 20	Non-Dipping *n* = 15	*p* - value
Total Time in Bed, min	442.5(371-490)	438(294-470)	0.407
Total Sleep Time, min (*)	382.8(43.2)	347.5(67.7)	0.069
Sleep Efficiency %	87.5(64.7-97.1)	82.0(50.8-97.3)	0.057
Sleep Latency, min	6.0(0-23)	4.0(0-31)	0.352
REM Sleep Latency, min	92(6.5-380)	91.5(50-389)	0.727
Wake after Sleep Onset, min	26.5(7-119)	67(10-174)	**0.028**
Sleep N1, % (*)	24.4(13.7)	27.9(13.3)	0.464
Sleep N2, % (*)	54.9(10.5)	54.1(11.1)	0.812
Sleep N3, %	0(0-13)	0(0-14)	0.961
Sleep R, %	17.5(7-31)	14(0-27)	0.296
Number of awakenings	27.5(6-90)	36(15-84)	0.260
Number sleep transitions (*)	145.4(58.4)	166.9(68.8)	0.328
Overall arousal index (# Arousal/Sleep hour)	24.4(2.9-81.3)	20.7(7.7-71.8)	0.884
Periodic leg movement index (#PLMS/Sleep hour)	3.3(0-42.9)	1.7(0-69)	0.591
Apnea/hypopnea Index(#Apneas + #Hypopnes)/Sleep hour	21.7(5-97.7)	24.8(5.6-80.7)	0.884
Oxygen desaturation index (# O_2 Desaturation ≥3%/Sleep hour)	58.9(8-121)	42.9(22.9-361)	0.884
SpO_2 % nadir during sleep (*)	75.0(12.4)	70.1(11.6)	0.244
Mean awake SpO_2 % (*)	95.2(1.8)	94.7(1.7)	0.443

Data represent median values, (Min-Max); *p* - value for Wilcoxon–Mann–Whitney U two-sample test. (*) Data represent mean values, (SD); *p* - value for independent samples Student´s *t* - Test. TST: Total Sleep Time; OSA: Obstructive Sleep Apnea; AHI: Apnea Hypopnea Index

p = 0.096). In contrast, the AUC for WASO was significant (AUC = 0.762 ± 0.087, 95% CI: 0.592–0.931, *p* = 0.009). The optimal cutoff point for WASO was determined to be 35 minutes, with a sensitivity of 0.800 and a specificity of 0.650.



Curve: AUC

Table 5: Logistic Regression Models Estimating Variables Associated with Non-dipping Status.

Model 1 Variables	B Coefficient	Wald	Exp (B)	Lower 95% C.I.	Upper 95% C.I.	*p* - value
Age years	0.090	1.349	1.094	0.940	1.273	0.245
BMI	-0.215	1.994	0.807	0.599	1.087	0.158
Triglycerides	-0.019	1.448	0.981	0.951	1.012	0.229
AASI	7.702	3.685	2212	0.851	575060	0.055
WASO	0.085	4.620	1.088	1.007	1.175	**0.032**
Insomnia ≥ 2 years	2.173	2.124	8.786	0.473	163.304	0.145
Chi-square overall model= 28.66, $p < 0.0001$. A decrease in nocturnal BP less than 10% was designated as 1 and 0 if the BP decrease was ≥ 10% - 20%.						
Final Model 1	**B Coefficient**	**Wald**	**Exp(B)**	**Lower 95% C.I.**	**Upper 95% C.I.**	***p* - value**
AASI	2.244	3.626	9.430	0.936	94.961	0.057
WASO	0.054	6.481	1.056	1.013	1.101	**0.011**
Insomnia ≥ 2 years	2.912	5.787	18.391	1.715	197.230	**0.016**
Chi-square overall model =20.86, $p < 0.0001$. R^2 Nagelkerke = 0.603.						
Model 2 Variables	**B Coefficient**	**Wald**	**Exp(B)**	**Lower 95% C.I.**	**Upper 95% C.I.**	***p* - value**
Age years	0.094	1.404	1.098	0.940	1.283	0.236
BMI	-0.164	1.775	0.849	0.667	1.080	0.183
Hemoglobin A1c	0.482	0.269	1.619	0.262	10.007	0.604
AASI	6.690	3.534	804	0.752	859638	0.060
WASO	0.080	5.244	1.083	1.012	1.160	0.022
Insomnia ≥ 2 Years	2.626	3.613	13.817	0.921	207	0.057
Final Model 2	**B Coefficient**	**Wald**	**Exp(B)**	**Lower 95% C.I.**	**Upper 95% C.I.**	***p* - value**
AASI	2.244	3.626	9.430	0.936	94.961	0.057
WASO	0.54	6.481	1.056	1.013	1.101	**0.011**
Insomnia ≥ 2 Years	2.912	5.787	18.391	1.715	197.23	**0.016**
Chi-square overall model = 25.28, $p = 0.0001$; R^2 Nagelkerke = 0.691						

Because of limited sample size, separate regression models were employed to conserve degrees of freedom. Both models included: age, BMI, AASI, WASO and chronic insomnia, with Model 1 also including triglycerides and Model 2, alternatively, also including hemoglobin A1C. For both Model 1 and Model 2, final models, limited to AASI, WASO and chronic insomnia, are also shown.

Discussion

In a final sample of 35 patients diagnosed with moderate to severe OSA, slightly fewer than half exhibited a non-dipping blood pressure pattern during 24-hour ABPM. The severity of OSA did not predict a non-dipping pattern. However, WASO and the chronicity of insomnia were significant predictors, independent of anthropometric, metabolic, or vascular stiffness factors. ROC curve analysis indicated that WASO had moderate predictive accuracy value, with a cutoff point of 35 minutes.

This appears to be the first report on the prevalence of non-dipping blood pressure in a Mexican population with mixed European and indigenous ancestry, specifically in patients with OSA living at moderate altitudes (2,240 meters above sea level). Our findings fall within the prevalence range reported in the literature. A recent meta-analysis of 14 studies, with 66% of participants of Asian origin, conducted by Cuspidi et al. [21], reported a pooled prevalence of 59%, although higher rates (up to 84%) have been reported in other studies [32]. The variability in prevalence seems to be influenced by racial disparities in the non-dipping pattern. For example, Booth et al. [33], reported that black individuals exhibited a statistically significantly smaller decline in blood pressure, from wakefulness to sleep, than white individuals did, even after adjusting for multiple variables. In our sample of Mexican individuals receiving tertiary-level care, non-African Americans and non-Asians were included.

Using a different methodology, longitudinal data over a 7.2-year period demonstrated a significant association between baseline OSA severity and the development of nocturnal systolic BP non-dipping in participants who initially exhibited normal nocturnal dipping [20]. Notably, Mokhlesi et al. [34], reported that, in a population-based sample, Rapid eye movement (REM)-related OSA was independently associated with the onset of BP non-dipping. Future longitudinal clinical studies are needed to further confirm these findings.

In our cross-sectional analysis of variables associated with non-dripping in OSA patients, we included measures of glycemic control, which previous studies have emphasized as important [35]. Although glycosylated hemoglobin and triglycerides differed between dippers and non-dippers, these associations lost significance in multivariate analyses. Another potential factor, arterial stiffness—an indicator of vascular tone and endothelial function and often considered an independent risk factor for cardiovascular disease—also became nonsignificant after adjustment. Our data suggest that only variables related to poor sleep quality, particularly objective measures such as the WASO, predict non-dipping status. These findings are consistent with studies showing that poor sleep quality can affect nighttime BP regulation, even in the absence of OSA [36]. These results suggest that for some patients, treating OSA alone (e.g., with continuous positive airway pressure (CPAP)) may not fully reverse normal nocturnal BP declines without also addressing sleep quality. Future clinical intervention studies are needed to test this hypothesis.

Interestingly, and perhaps not coincidentally, high altitude has known to affect sleep quality [37] and can negatively impact breathing during sleep [38]. These effects are typically acute and resolve over time with prolonged exposure to elevation. Since all of our patients resided at moderate altitude, they were likely acclimatized to these conditions. However, it remains possible that the poor sleep quality observed in our study sample may partially reflect residual effects of altitude [39].

Acknowledgment

This work was supported by UNAM-PAPIIT 32-IN216919.

We thank and gratefully acknowledge Dr. Daniel Illescas Zarate for his valuable input on the manuscript.

Authors' contributions

All authors contributed to this work and had final approval of the submitted and published versions. MVF, VSA study design, patient recruitment, and data analysis; MF, interpretation of AMBP; DLB data analysis and manuscript writing; JOM, Medical diagnosis and treatment; CA, laboratory analysis; MR, GG, RMN, MM, polysomnographic studies.

Data availability

The data supporting this study's findings are available from the corresponding author upon reasonable request.

References

1. Hermida RC, Ayala DE, Mojon A, Fernández JR. Influence of circadian time of hypertension treatment on cardiovascular risk: results of the MAPEC study. Chronobiol Int. 2010;27:1629–1651. Available from: https://doi.org/10.3109/07420528.2010.510230
2. Hermida RC, Ayala DE, Mojon A, Fernández JR. Blunted sleep time relative blood pressure decline increases cardiovascular risk independent of blood pressure level – the "normotensive nondipper" paradox. Chronobiol Int. 2013;30:87–98. Available from: http://dx.doi.org/10.3109/07420528.2012.701127
3. O'Brien E, Sheridan J, O'Malley K. Dippers and non-dippers. Lancet. 1988;2:397. Available from: https://doi.org/10.1016/s0140-6736(88)92867-x
4. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, et al. Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. Hypertension. 2003;42(6):1206–1252. Available from: https://doi.org/10.1161/01.hyp.0000107251.49515.c2
5. Boggia J, Li Y, Thijs L, Hansen TW, Kikuya M, Björklund-Bodegård K, et al. Prognostic accuracy of day versus night ambulatory blood pressure: a cohort study. Lancet. 2007;370:1219–1229. Available from: https://doi.org/10.1016/s0140-6736(07)61538-4
6. Hansen TW, Li Y, Boggia J, Thijs L, Richart T, Staessen JA. Predictive role of the nighttime blood pressure. Hypertension. 2011;57:3–10. Available from: https://doi.org/10.1161/hypertensionaha.109.133900

7. Kario K, Kanegae H, Tomitani N, Okawara Y, Fujiwara T, Yano Y, Hoshide S. Nighttime blood pressure measured by home blood pressure monitoring as an independent predictor of cardiovascular events in general practice. Hypertension. 2019;73:1240–1248. Available from: https://doi.org/10.1161/hypertensionaha.118.12740
8. de la Sierra A, Redon J, Banegas JR, Segura J, Parati G, Gorostidi M, et al. Prevalence and factors associated with circadian blood pressure patterns in hypertensive patients. Hypertension. 2009;53:466–472. Available from: https://doi.org/10.1161/hypertensionaha.108.124008
9. Eguchi K, Pickering TG, Hoshide S, Ishikawa J, Ishikawa S, Schwartz JE, et al. Ambulatory blood pressure is a better marker than clinic blood pressure in predicting cardiovascular events in patients with/without type 2 diabetes. Am J Hypertens. 2008;21(4):443–450. Available from: https://doi.org/10.1038/ajh.2008.4
10. Fagard RH, Thijs L, Staessen JA, Clement DL, De Buyzere ML, De Bacquer DA. Night-day blood pressure ratio and dipping pattern as predictors of death and cardiovascular events in hypertension. J Hum Hypertens. 2009;23:645–653. Available from: https://doi.org/10.1038/jhh.2009.9
11. Hermida RC, Ayala DE, Mojón A, Fernández JR. Decreasing sleep-time blood pressure determined by ambulatory monitoring reduces cardiovascular risk. J Am Coll Cardiol. 2011;58(11):1165–1173. Available from: https://doi.org/10.1016/j.jacc.2011.04.043
12. Dodt C, Breckling U, Derad I, Fehm HL, Born J. Plasma epinephrine and norepinephrine concentrations of healthy humans associated with nighttime sleep and morning arousal. Hypertension. 1997;30(1 Pt 1):71–76. Available from: https://doi.org/10.1161/01.hyp.30.1.71
13. Vaile JC, Stallard TJ, al-Ani M, Jordan PJ, Townend JN, Littler WA. Sleep and blood pressure: spontaneous baroreflex sensitivity in dippers and non-dippers. J Hypertens. 1996;14:1427–1432. Available from: https://doi.org/10.1097/00004872-199612000-00007
14. Sachdeva A, Weder AB. Nocturnal sodium excretion, blood pressure dipping, and sodium sensitivity. Hypertension. 2006;48:527–533. Available from: https://doi.org/10.1161/01.hyp.0000240268.37379.7c
15. Afsar B, Sezer S, Elsurer R, Ozdemir FN. Is HOMA index a predictor of nocturnal non-dipping in hypertensives with newly diagnosed type 2 diabetes mellitus? Blood Press Monit. 2007;12(3):133–139. Available from: https://doi.org/10.1097/mbp.0b013e3280b08379
16. Aung AT, Chan SP, Kyaing TT, Lee CH. Diabetes mellitus is associated with high sleep-time systolic blood pressure and non-dipping pattern. Postgrad Med. 2020;132(4):346–351. Available from: https://doi.org/10.1080/00325481.2020.1745537
17. Nikolaidou B, Anyfanti P, Gavriilaki E, Lazaridis A, Triantafyllou A, Zarifis H, et al. Non-dipping pattern in early-stage diabetes: association with glycemic profile and hemodynamic parameters. J Hum Hypertens. 2022;36(9):805–810. Available from: https://doi.org/10.1038/s41371-021-00587-4
18. Wolf J, Hering D, Narkiewicz K. Non-dipping pattern of hypertension and obstructive sleep apnea syndrome. Hypertens Res. 2010;33(9):867–871. Available from: https://doi.org/10.1038/hr.2010.153
19. Pio-Abreu A, Moreno H Jr, Drager LF. Obstructive sleep apnea and ambulatory blood pressure monitoring: current evidence and research gaps. J Hum Hypertens. 2021;35(4):315–324. Available from: https://doi.org/10.1038/s41371-020-00470-8
20. Hla KM, Young T, Finn L, Peppard PE, Szklo-Coxe M, Stubbs M. Longitudinal association of sleep-disordered breathing and non-dipping of nocturnal blood pressure in the Wisconsin Sleep Cohort Study. Sleep. 2008;31(6):795–800. Available from: https://doi.org/10.1093/sleep/31.6.795
21. Cuspidi C, Tadic M, Sala C, Gherbesi E, Grassi G, Mancia G. Blood pressure non-dipping and obstructive sleep apnea syndrome: a meta-analysis. J Clin Med. 2019;8(9):1367. Available from: https://doi.org/10.3390/jcm8091367
22. Pinilla L, Benítez ID, Gracia-Lavedan E, Torres G, Minguez O, Aguilà M, et al. Polysomnographic characterization of circadian blood pressure patterns in patients with obstructive sleep apnea. Sleep. 2023;46(4):zsad031. Available from: https://doi.org/10.1093/sleep/zsad031
23. Valencia-Flores M, Castaño VA, Campos RM, Rosenthal L, Resendiz M, Vergara P, et al. The siesta culture concept is not supported by the sleep habits of urban Mexican students. J Sleep Res. 1998;7(1):21–29. Available from: https://doi.org/10.1046/j.1365-2869.1998.00087.x
24. Kario K, Pickering TG, Umeda Y, Hoshide S, Hoshide Y, Morinari M, et al. Morning surge in blood pressure as a predictor of silent and clinical cerebrovascular disease in elderly hypertensives: a prospective study. Circulation. 2003;107(10):1401–1406. Available from: https://doi.org/10.1161/01.CIR.0000056521.67546.AA
25. Bilo G, Grillo A, Guida V, Parati G. Morning blood pressure surge: pathophysiology, clinical relevance and therapeutic aspects. Integr Blood Press Control. 2018;11:47–56. Available from: https://www.tandfonline.com/doi/full/10.2147/IBPC.S130277
26. Kikuya M, Staessen JA, Ohkubo T, Thijs L, Metoki H, Asayama K, et al. Ambulatory arterial stiffness index and 24-hour ambulatory pulse pressure as predictors of mortality in Ohasama, Japan. Stroke. 2007;38:1161–1166. Available from: https://doi.org/10.1161/01.STR.0000259604.67283.69
27. Bastos JM, Bertoquini S, Polonia J. Prognostic significance of ambulatory arterial stiffness index in hypertensives followed for 8.2 years: its relation with new events and cardiovascular risk estimation. Rev Port Cardiol. 2010;29:1287–1303. Available from: https://europepmc.org/article/med/21179973
28. Gijón-Conde T, Gorostidi M, Banegas JR, de la Sierra A, Segura J, Vinyoles E, et al. Documento de la Sociedad Española de Hipertensión-Liga Española para la Lucha contra la Hipertensión Arterial (SEH-LELHA) sobre monitorización ambulatoria de la presión arterial (MAPA) 2019. Hipertens Riesgo Vasc. 2019;36(4):199–212. Spanish. Available from: https://doi.org/10.1016/j.hipert.2019.05.002
29. Williams B, Mancia G, Spiering W, Agabiti Rosei E, Azizi M, Burnier M, et al. 2018 Practice guidelines for the management of arterial hypertension of the European Society of Hypertension and the European Society of Cardiology: ESH/ESC Task Force for the Management of Arterial Hypertension. J Hypertens. 2018;36:2284–2309. [No direct link provided; typically accessible via institutional subscriptions]
30. Berry RB, Quan SF, Abreu AR; for the American Academy of Sleep Medicine. AASM manual for the scoring of sleep and associated events: rules, terminology and technical specifications. Version 2.6. Darien (IL): American Academy of Sleep Medicine; 2020.
31. American Diabetes Association. 2. Classification and diagnosis of diabetes: standards of medical care in diabetes—2019. Diabetes Care. 2019;42(Suppl 1):S13–S28. Available from: https://doi.org/10.2337/dc19-s002
32. Loredo JS, Ancoli-Israel S, Dimsdale JE. Sleep quality and blood pressure dipping in obstructive sleep apnea. Am J Hypertens. 2001;14(9 Pt 1):887–892. Available from: https://doi.org/10.1016/s0895-7061(01)02143-4
33. Booth JN, Anstey DE, Bello NA, Jaeger BC, Pugliese DN, Thomas SJ, et al. Race and sex differences in asleep blood pressure: the Coronary Artery Risk Development in Young Adults (CARDIA) study. J Clin Hypertens (Greenwich). 2019;21(2):184–192. Available from: https://doi.org/10.1111/jch.13474
34. Mokhlesi B, Finn LA, Hagen EW, Young T, Hla KM, Van Cauter E, et al. Obstructive sleep apnea during REM sleep and hypertension: results of the Wisconsin Sleep Cohort. Am J Respir Crit Care Med. 2014;190(10):1158–1167. Available from: https://doi.org/10.1164/rccm.201406-1136OC
35. Afsar B, Sezer S, Elsurer R, Ozdemir FN. Is the HOMA index a predictor of nocturnal non-dipping in hypertensive patients with newly diagnosed type 2 diabetes mellitus? Blood Press Monit. 2007;12(3):133–139. Available from: https://doi.org/10.1097/MBP.0b013e3280b08379
36. Loredo JS, Nelesen R, Ancoli-Israel S, Dimsdale JE. Sleep quality and blood pressure dipping in normal adults. Sleep. 2004;27(6):1097–1103. Available from: https://doi.org/10.1093/sleep/27.6.1097

37. Bloch KE, Buenzli JC, Latshang TD, Ulrich S. Sleep at high altitude: guesses and facts. J Appl Physiol (1985). 2015;119(12):1466–1480. Available from: https://doi.org/10.1152/japplphysiol.00448.2015

38. Furian M, Bitos K, Hartmann SE, Muralt L, Lichtblau M, Bader PR, et al. Acute high-altitude exposure, acclimatization and re-exposure on nocturnal breathing. Front Physiol. 2022;13:965021. Available from: https://doi.org/10.3389/fphys.2022.965021

39. Kinsman TA, Townsend NE, Gore CJ, Hahn AG, Clark SA, Aughey RJ, et al. Sleep disturbance at simulated altitude indicated by stratified respiratory disturbance index but not hypoxic ventilatory response. Eur J Appl Physiol. 2005;94:569–575. Available from: https://doi.org/10.1007/s00421-005-1368-6