ORIGINAL ARTICLE

DOI: 10.20515/otd. 1911835

Osmangazi Journal of Med, 2026;48(5):827-837

Osmangazi Journal of Medicine

e-ISSN: 2587-1579

Effect of Total Water Percentage on Circadian Blood Pressure Variation in Prehypertensive Patients

Prehipertansif Hastalarda Toplam Vücut Suyu Yüzdesinin Sirkadiyen Kan Basıncı Değişimine Etkisi

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Received : 18.03.2026

Accepted : 17.06. 2026

Abstract: Circadian changes in blood pressure are a key factor in determining cardiovascular risk. A normal dipper pattern shows a decrease in blood pressure at night, whereas a non-dipper pattern shows a smaller decrease at night. Changes in the distribution of bodily fluids may affect how blood vessels work and how blood pressure changes over the course of a day. This study aimed to examine the correlation between total body water percentage and circadian blood pressure patterns in individuals classified as prehypertensive. This retrospective cross-sectional study comprised 300 prehypertensive individuals who underwent 24-hour ambulatory blood pressure monitoring and body composition measurement via bioelectrical impedance. Patients were classified into two groups according to the magnitude of nocturnal blood pressure decline: dipper and non-dipper. Clinical, echocardiographic, and hydration characteristics were compared between the dipper and non-dipper groups. In the study population, 124 patients exhibited a dipper pattern, while 176 displayed a non-dipper pattern. Non-dipper patients exhibited a markedly reduced total body water percentage in comparison to dipper persons. Echocardiographic measures, such as interventricular septal thickness and left ventricular end-diastolic diameter, were markedly elevated in the non-dipper cohort. In multivariable logistic regression analysis, total body water percentage persisted as an independent predictor of non-dipper blood pressure pattern. A lower percentage of total body water is linked to a non-dipper blood pressure pattern in individuals who are prehypertensive. These findings indicate that modifications in body fluid content may play a role in circadian blood pressure dysregulation and heightened cardiovascular risk.

Keywords: Prehypertension; Circadian blood pressure; Non-dipper hypertension; Total body water; Bioelectrical impedance

Ethics Committee Approval: The study was approved by Trabzon University Non-Interventional Clinical Research Ethics Committee (Decision No: 2026/02, Date: 02.02.2026).

Informed Consent: The authors state that informed consent was not applicable due to the nature of the study.

Authorship Contributions: The authors confirm contribution to the paper as follows: Both of authors contributed to the study conception and design. Material preparation and data collection were performed by AÖ. Data analysis and interpretation: AC. The first draft of the manuscript was written by AC. Study supervision and fundings materials were performed by AC and both of authors commented on previous versions of the manuscript. The authors read and approved the final manuscript.

Copyright Transfer Form: Copyright Transfer Form was signed by author.

Peer-review: Externally peer-reviewed.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The author declared that

Özet: Kan basıncındaki sirkadiyen değişiklikler, kardiyovasküler riski belirlemede önemli bir faktördür. Normal bir "dipper" paterni, gece kan basıncında bir düşüş gösterirken, "non-dipper" paterni gece daha az bir düşüş gösterir. Vücut sıvılarının dağılımındaki değişiklikler, kan damarlarının nasıl çalıştığını ve kan basıncının gün boyunca nasıl değiştiğini etkileyebilir. Bu çalışma, prehipertansif olarak sınıflandırılan bireylerde toplam vücut suyu yüzdesi ile sirkadiyen kan basıncı paternleri arasındaki korelasyonu incelemeyi amaçlamıştır. Bu retrospektif kesitsel çalışma, 24 saatlik ambulatuvar kan basıncı izlemesi ve biyoelektrik empedans yoluyla vücut kompozisyonu ölçümü yapılan 300 prehipertansif bireyi içermiştir. Hastaları, gece kan basınçlarının ne kadar düştüğüne göre iki gruba ayırdık: dipper ve non-dipper. Gruplar arasındaki klinik, ekokardiyografik ve hidrasyon özelliklerindeki farklılıkları inceledik. Çalışma popülasyonunda 124 hasta dipper paterni gösterirken, 176 hasta non-dipper paterni göstermiştir. Kan basıncında gece düşüşü göstermeyen hastalarda, gece düşüşü gösteren kişilere kıyasla toplam vücut suyu yüzdesi belirgin şekilde azalmıştır. İnterventriküler septal kalınlık ve sol ventrikül diyastol sonu çapı gibi ekokardiyografik ölçümler, gece düşüşü göstermeyen grupta belirgin şekilde yüksek bulunmuştur. Çok değişkenli lojistik regresyon analizinde, toplam vücut suyu yüzdesi, gece düşüşü göstermeyen kan basıncı paterninin bağımsız bir belirleyicisi olarak kalmıştır. Daha düşük toplam vücut suyu yüzdesi, prehipertansif kişilerde gece düşüşü göstermeyen kan basıncı paterniyle ilişkilidir. Bu bulgular, vücut sıvı içeriğindeki değişikliklerin sirkadiyen kan basıncı düzensizliğinde ve artmış kardiyovasküler riskte rol oynayabileceğini göstermektedir.

Anahtar Kelimeler: Prehipertansiyon; Sirkadiyen kan basıncı; Non-dipper hipertansiyon; Toplam vücut suyu; Biyoelektrik empedans

How to cite/ Atıf için: Cimbek A , Özderya A, Effect of Total Water Percentage on Circadian Blood Pressure Variation in Prehypertensive Patients, Osmangazi Journal of Medicine, 2026;48(5):827-837

1. Introduction

Hypertension remains a major global health concern and is a leading contributor to cardiovascular morbidity and mortality. It is strongly associated with adverse outcomes, including myocardial infarction, stroke, heart failure, and chronic kidney disease. In recent years, increasing attention has been directed toward the complex physiological mechanisms regulating blood pressure beyond single office measurements, particularly the role of circadian rhythms in cardiovascular homeostasis. (1).

Blood pressure follows a circadian pattern characterized by higher daytime levels and a physiological decline during nocturnal sleep. Under normal conditions, systolic and diastolic blood pressure decrease by approximately 10–20 percent during the night compared to daytime values. Individuals who exhibit this normal nocturnal decline in blood pressure are classified as “dippers,” whereas those with a reduction of less than 10 percent are defined as “non-dippers.” In some cases, blood pressure may increase during the night, a pattern referred to as “reverse dipping. (2).

Unusual circadian blood pressure patterns have been demonstrated to possess significant prognostic consequences. Many studies have demonstrated that a non-dipper blood pressure pattern is associated with increased cardiovascular morbidity, target organ damage, and all-cause mortality, independent of daytime blood pressure levels. These adverse outcomes include left ventricular hypertrophy, chronic kidney disease progression, carotid atherosclerosis, stroke, and major cardiovascular events (3–9). Individuals who do not exhibit a nocturnal blood pressure dipping pattern have structural and functional problems with their hearts and blood vessels. These problems include left ventricular hypertrophy, increased arterial stiffness, endothelial dysfunction, carotid atherosclerosis, and reduced kidney function. These findings suggest that disturbances in circadian blood pressure regulation may represent an early pathophysiological marker of cardiovascular disease. The mechanisms underlying the non-dipper phenotype are complex and multifactorial (3-7). The suggested causes include problems with the autonomic nervous system, more sympathetic activity at night, trouble getting rid of salt, sleep disorders such obstructive sleep apnea, and problems with the endothelium (8). Changes in how the body controls fluids and the amount of blood vessels may also be crucial for controlling blood pressure at different times of the day. Changes in the amount and distribution of fluids inside blood vessels can affect vascular resistance, cardiac preload, and neurohormonal activation. All of these things can change blood pressure variability and cause blood pressure to drop at night (9).

The composition of body fluids is a key factor in how the cardiovascular system works. Total body water (TBW) is a fundamental determinant of cardiovascular physiology and is distributed between intracellular and extracellular compartments. It plays a critical role in maintaining vascular volume, electrolyte balance, and hemodynamic stability. Even subtle changes in hydration status may influence blood pressure regulation through effects on plasma volume, vascular tone, and renal sodium handling. Consequently, modifications in body fluid content may have a role in the pathogenesis of hypertension and irregular circadian blood pressure patterns (10).

Bioelectrical impedance analysis (BIA) is a widely used, non-invasive method for assessing body composition and hydration status. Previous studies have demonstrated associations between hydration parameters and blood pressure regulation; however, the relationship between total body water percentage and circadian blood pressure patterns remains insufficiently investigated, particularly in prehypertensive individuals. Although recent guidelines have updated blood pressure classifications, the concept of early blood pressure dysregulation remains clinically relevant in this population (11, 12). For example, individuals with high blood pressure have been shown to have a lower total body water percentage and a different balance of intracellular and extracellular fluid than individuals with normal blood pressure. These results indicate that hydration status may affect blood pressure control and cardiovascular risk (10, 11). There is growing interest in the link between hydration status and cardiovascular physiology, however the link between total body water percentage and circadian blood pressure patterns hasn't been studied enough. There isn't much data that looks at this association in those who are prehypertensive (11, 13). Prehypertension is a stage between normal blood pressure and established hypertension. It raises the chance of developing overt hypertension and cardiovascular disease. Finding physiological parameters linked to aberrant circadian blood pressure rhythms in this group may aid with early cardiovascular risk assessment and shed light on how hypertension develops (10, 11, 14).

To the best of our knowledge, this is one of the few studies specifically investigating the relationship between total body water percentage and circadian blood pressure patterns in prehypertensive individuals. We hypothesized that a diminished total body water percentage correlates with a non-dipper blood pressure pattern in prehypertensive patients, indicating that modifications in body fluid composition may lead to disrupted circadian blood pressure regulation and heightened cardiovascular risk. The principal objective of this study was to assess the relationship between total body water percentage and circadian blood pressure trends (dipper versus non-dipper) in prehypertensive individuals. A secondary objective was to ascertain if total body water percentage functions as an independent predictor of non-dipper blood pressure pattern subsequent to the adjustment for echocardiographic and clinical factors.

2. Materials and Methods

2.1. Study Design

This study was structured as a retrospective cross-sectional observational investigation involving prehypertensive individuals assessed at the cardiology and internal medicine outpatient clinics of our institution from January 2021 to December 2023.

Blood pressure classification in this study was defined within the range corresponding to early-stage blood pressure elevation, based on systolic blood pressure values of 120-139 mmHg and/or diastolic blood pressure values of 80-89 mmHg, calculated as the average of at least three office measurements. This range aligns with contemporary international guideline classifications, including the Eighth Report of the Joint National Committee (JNC-8) and the 2024 European Society of Cardiology (ESC) recommendations, corresponding to the “high-normal” blood pressure category and overlapping with the “elevated blood pressure” category described in other major guidelines (15, 16). Therefore, the study population was defined and interpreted in accordance with current clinical classification frameworks.

The study comprised 300 individuals who were prehypertensive and had access to ambulatory blood pressure monitoring (ABPM), echocardiographic examination, and body composition measurement.

The local institutional ethics committee approved the study protocol, and the study was carried out in conformity with the Declaration of Helsinki.

Inclusion and Exclusion Criteria

Inclusion criteria

- Age ≥18 years
- Prehypertensive blood pressure levels
- Availability of 24-hour ambulatory blood pressure monitoring
- Availability of bioelectrical impedance analysis for body composition

Exclusion criteria

Patients were excluded if they had:

- Established hypertension (≥140/90 mmHg)
- Heart failure
- Moderate or severe valvular heart disease
- Chronic kidney disease stage 3-4
- Liver failure
- Active infection or inflammatory disease
- Malignancy
- Incomplete ABPM recordings (<70 percent valid measurements)

Diabetes mellitus was not defined as an exclusion criterion to preserve the representativeness of the study population. Diabetes status was systematically recorded and assessed as a potential variable in the statistical analysis.

a. Blood Pressure Measurement

We used a validated automated oscillometric instrument (Omron HEM-7201, Omron, Dalian, China) to monitor blood pressure. Measurements were taken while sitting down, after five minutes of rest, and without caffeine, exercise, or smoking for at least 30 minutes. The average of three consecutive measurements was recorded.

2.2. 24-Hour Ambulatory Blood Pressure Monitoring

The SCHILLER BR-102 plus device (medilog DARWIN2 software) was used to check blood pressure while the person was walking. The cuff was put on the arm that wasn't the dominant one.

Every 30 minutes from 6:00 AM to 10:00 PM, measurements were taken.

Every hour between 22:00 and 06:00, measurements were taken.

For an ABPM recording to be legitimate, at least 70 percent of the measurements had to be successful.

The magnitude of nocturnal BP dipping was calculated as (nocturnal SBP–daytime SBP) × 100/daytime SBP (17).

Patients were classified as:

Dipper: ≥10 percent nocturnal SBP decline

Non-dipper: <10 percent nocturnal SBP decline

2.3. Body Composition Assessment

Bioelectrical impedance analysis (BIA) with the TANITA BC-601 equipment (Tanita Corporation, Arlington Heights, IL, USA) was used to measure body composition. Tests were done in the morning under the same conditions:At least 8-hour fasting

After bladder emptying

Without heavy exercise within the previous 12 hours

The following parameters were recorded; Total body water weight (kg), Total body water percentage (TBW%), TBW percentage was used as the primary fluid-related variable in accordance with the study.

2.4. Laboratory and Echocardiographic Evaluation

Fasting venous blood samples were collected after at least 8 hours of fasting. Routine biochemical analyses included; Fasting glucose, Lipid profile, Renal and liver function tests, Electrolytes, Complete blood count.

Echocardiography was performed using a Philips Affiniti 50 system (X4-2 probe, Philips Medical Systems, Andover, MA, USA). Left ventricular ejection fraction (LVEF) was calculated using the modified Simpson method. The following structural parameters were recorded; Left ventricular end-diastolic diameter (LV-EDD), Interventricular septum thickness (IVS), Posterior wall thickness (PW), Left atrial diameter (LA), Mitral inflow early (E wave) and late (A wave) velocities.

Statistical Analysis

Statistical analyses were conducted utilizing SPSS software for Windows version 20.0 (SPSS Inc., Chicago, IL, USA). Patients were categorized into two groups based on their circadian blood pressure pattern: dipper and non-dipper. We used the Kolmogorov–Smirnov test to check if the variables were normally distributed and if the variances were the same. The independent samples t-test was used to compare groups when the variables had a normal distribution. The Mann–Whitney U test was employed when the variables did not have a normal distribution. The Chi-square test was used to compare categorical variables. Parametric continuous variables were represented as mean ± standard deviation, while non-parametric variables were depicted as median (minimum–maximum). We showed categorical variables as both numbers and percentages. Receiver operating characteristic (ROC) curve analysis was used to find the best cut-off value for total body water percentage for predicting the non-dipper pattern. The sensitivity and specificity values were then computed. We performed binary logistic regression analysis to find the dependent and independent factors that affect the occurrence of the non-dipper blood pressure pattern. A p-value of less than 0.05 was deemed statistically significant.

3. Results

3.1. Study Population and Baseline Characteristics

A total of 300 prehypertensive individuals were included in the study. According to ambulatory blood pressure monitoring results, 124 patients exhibited a dipper blood pressure pattern, whereas 176 patients demonstrated a non-dipper pattern, corresponding to a prevalence of 58.6 percent for the non-dipper phenotype in the study population.

The mean age of patients in the dipper group was 59.56 ± 10.88 years, while the mean age of the non-dipper group was 61.5 ± 11.39 years, with no statistically significant difference between groups ($p = 0.141$).

The demographic, laboratory, echocardiographic and body composition parameters of the study population are presented in Table 1. There were no significant differences between dipper and non-dipper groups in terms of age, gender distribution, diabetes mellitus prevalence, coronary artery disease, chronic kidney disease, smoking status ($p > 0.05$). Also, body mass index was not significantly different between dipper and non-dipper groups (p >0.05).

Similarly, hematological and biochemical laboratory parameters including hemoglobin, hematocrit, white blood cell count, platelet count, creatinine, estimated glomerular filtration rate, glucose, liver enzymes, electrolytes, albumin, lipid profile, and triglyceride levels were comparable between the two groups (Table 1).

3.2. Echocardiographic Results

Echocardiographic evaluation demonstrated several significant structural differences between dipper and non-dipper groups. Patients with a non-dipper blood pressure pattern exhibited larger left ventricular end-diastolic diameter (LV-EDD), increased interventricular septum thickness (IVS), increased posterior wall thickness (PW), lower E wave velocity compared with dipper patients. Specifically LV-EDD was significantly higher in the non-dipper group

(48 ± 4.75 mm vs 46.05 ± 4.28 mm; p < 0.001). IVS thickness was significantly greater in non-dipper patients (11 mm vs 10 mm; p < 0.001). PW thickness was also higher in the non-dipper group (p = 0.009). E wave velocity was significantly lower in the non-dipper group (62.15 ± 19.25 cm/s vs 68.22 ± 21.83 cm/s; p = 0.016). However, no significant differences were observed between groups regarding LV-ESD, A wave velocity, left atrial diameter (Table 1).

3.3. Body Composition Results

Body composition analysis revealed a significant difference in total body water percentage between groups. While total body water weight (kg) was not significantly different between dipper and non-dipper patients (48.70 ± 6.03 kg vs 50.23 ± 7.53 kg; p = 0.166), TBW percentage was significantly lower in the non-dipper group (50.54 ± 6.3 vs 59.89 ± 5.23; p < 0.001). These findings suggest that relative body fluid composition rather than absolute water mass may be associated with abnormal circadian blood pressure patterns. The comparison of body composition parameters between the two groups is illustrated in Figure 1.

3.4. ROC Curve Analysis

Receiver operating characteristic (ROC) curve analysis was performed to determine the predictive performance of total body water percentage for identifying the non-dipper blood pressure pattern. The ROC analysis demonstrated that total body water percentage had a strong discriminative ability for predicting the non-dipper with Area Under the Curve (AUC): 0.871, 95% Confidence Interval (CI): 0.832 – 0.909, p < 0.001. The optimal cut-off value for total body water percentage was determined as 55.5 percent, providing a sensitivity of 82.3 percent and a specificity of 79.5 percent for predicting the non-dipper blood pressure pattern (Figure 2).

3.5. Logistic Regression Analysis

To determine the predictors of the non-dipper blood pressure pattern, binary logistic regression analysis was performed.

3.5.1. Univariable Logistic Regression Analysis

In the univariable logistic regression analysis, several echocardiographic and body composition parameters were found to be significantly associated with the presence of a non-dipper blood pressure pattern. Specifically Interventricular septum thickness (IVS) was significantly associated with non-dipper status (OR = 1.607, 95% CI: 1.325–1.948, p = 0.001). Left ventricular end-diastolic diameter (LV-EDD) was also significantly associated with non-dipper pattern (OR = 1.095, 95% CI: 1.037–1.156, p = 0.001). E wave demonstrated a modest but statistically significant inverse association with the non-dipper phenotype (OR = 0.986, 95% CI: 0.974–0.998, p = 0.019). Total body water percentage showed a strong inverse association with non-dipper blood pressure pattern (OR = 0.770, 95% CI: 0.726–0.817, p < 0.001). In contrast, demographic and laboratory parameters such as age, body mass index, glomerular filtration rate, and albumin levels were not significantly associated with the presence of a non-dipper pattern in the univariable analysis (Table 2).

3.5.2. Multivariable Logistic Regression Analysis

Variables that demonstrated statistical significance in the univariable analysis were subsequently entered into a multivariable logistic regression model to identify independent predictors of non-dipper blood pressure pattern. In the multivariable analysis, interventricular septum thickness (IVS) remained an independent predictor of non-dipper status (OR = 1.826, 95% CI: 1.278–2.609, p = 0.001). Left ventricular end-diastolic diameter (LV-EDD) also remained independently associated with the non-dipper pattern (OR = 1.205, 95% CI: 1.103–

1.315, p = 0.001). Total body water percentage emerged as a strong independent predictor of the non-dipper blood pressure (OR = 0.687, 95% CI: 0.622–0.758, $p < 0.001$).

In this model, E wave lost statistical significance after adjustment for other variables (p = 0.775), suggesting that its association with non-dipper pattern was confounded by structural cardiac parameters. Overall, these findings indicate that increased interventricular septal thickness, larger left ventricular end-diastolic diameter, and lower total body water percentage were independently associated with the presence of a non-dipper blood pressure pattern (Table 2).

Table 1. Clinical characteristics of the study population

Parameters	Dipper Hypertension	Non-dipper hypertension	P value
Age (years)	59.56 ± 10.88	61.5 ± 11.39	0.141
Gender (F/M) (n)	30 / 94	40 / 136	0.783
Diabetes Mellitus n (%)	33	50	0.794
CKD n(%)	8	8	0.603
CAD n(%)	21	32	0.469
Smoker n(%)	38	68	0.178
Hemoglobin (g/dL)	13.94 ± 1.73	14.08 ± 1.74	0.487
Hematocrit (%)	43 (26-56)	44 (29-57)	0.467
MCV (fL)	89.5 (74-102)	90 (70-104)	0.295
WBC (x10^9/L)	9.9 (6.15-13.4)	10.07 (4.97-14.6)	0.410
PLT (x10^9/L)	219 (51-461)	223 (69-376)	0.919
Creatinine (mg/dL)	0.94 (0.56- 1.7)	0.88 (0.63-1.52)	0.311
GFR (mL/dak/1,73m²)	86 (34-114)	89 (42-118)	0.991
Glucose (mg/dL)	124 (74-324)	126 (92-316)	0.507
AST (U/L)	34 (15-291)	27.5 (10-270)	0.727
ALT (U/L)	24 (9-94)	23.5 (6-150)	0.728
Na (mmol/L)	138 (129-142)	137 (130-144)	0.583
K (mmol/L)	4.3 (3.7-4.9)	4.25 (3.2- 4.8	0.842
Albumin (g/dL)	39.5 (31.5-46.6)	40.3 (27.8-51)	0.641
LDL (mg/dL)	132.5 (68-154)	135 (77-195)	0.945
HDL (mg/dL)	46.2 (28-84)	43.3 (33-68)	0.236
Triglycerides (mg/dL)	127 (52-435)	122 (66-287)	0.160
Total Cholesterol (mg/dL)	196 (133-369)	208 (107-375)	0.381
LV-EF (%)	60 (55-65)	57.5 (50-65)	**<0.001**
LV-EDD (mm)	46.05 ± 4.28	48 ± 4.75	**<0.001**
LV-ESD (mm)	32.83 ± 5.78	33.42 ± 5.82	0.122

IVS (mm)	10 (8-13)	11 (9-15)	**<0.001**
PW (mm)	10 (8-13)	10 (9-13)	**0.009**
LA (mm)	43.83 ± 6.26	37.49 ±4.52	0.077
E wave (cm/s)	68.22 ±21.83	62.15 ± 19.25	**0.016**
A wave (cm/s)	69.29 ± 14.64	69.65 ± 17.18	0.861
Total Water Weight (kg)	48.70 ± 6.03	50.23 ± 7.53	0.166
Total Water Percentage (%)	59.89 ± 5.23	50.54 ± 6.35	**<0.001**

WBC: White Blood Cell count, GFR: Estimated Glomerular Filtration Rate, HDL-C: High-Density Lipoprotein Cholesterol, LDL-C: Low-Density Lipoprotein Cholesterol, AST: Aspartate Aminotransferase, ALT : Alanine Aminotransferase,
Left ventricular ejection fraction (LVEF), interventricular septum thickness (IVS), posterior wall thickness (PW), Left atrial diameter (LA), Mitral inflow early (E wave) late (A wave) velocities, left ventricular end-diastolic diameter (LV-EDD), left ventricular end-sistolic diameter(LV-ESD), Chronic kidney disease (CKD), Coronary artery disease(CAD),

Table 2. Univariable and multivariable regression analysis showing the relationship non-dipper pattern and parameters

	Univariable			Multivariable		
Variables	OR	CI95%	p	OR	CI95%	p
IVS	1.607	1.325-1.948	**0.001**	1.826	1.278-2.609	**0.001**
LV-EDD	1.095	1.037-1.156	**0.001**	1.205	1.103-1.315	**0.001**
E wave	0.986	0.974-0.998	**0.019**	0.997	0.980-1.015	0.775
Total Water Percentage	0.770	0.726-0.817	**<0.001**	0.687	0.622-0.758	**<0.001**

Left ventricular end-diastolic diameter (LV-EDD), interventricular septum thickness (IVS), Mitral inflow early (E wave)

1

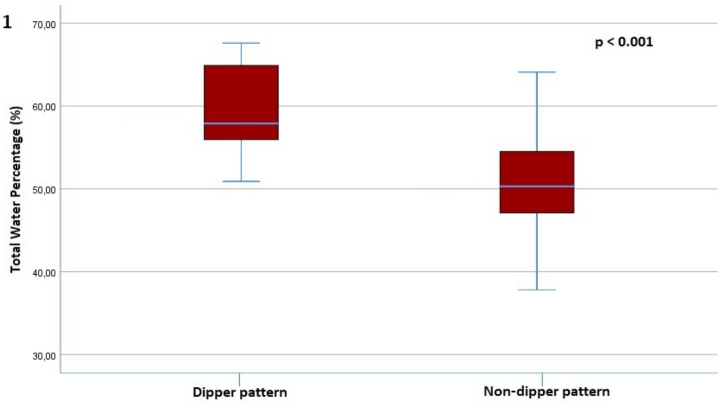

Figure 1. Comparison of total body water percentage between dipper and non-dipper blood pressure patterns in prehypertensive patients.

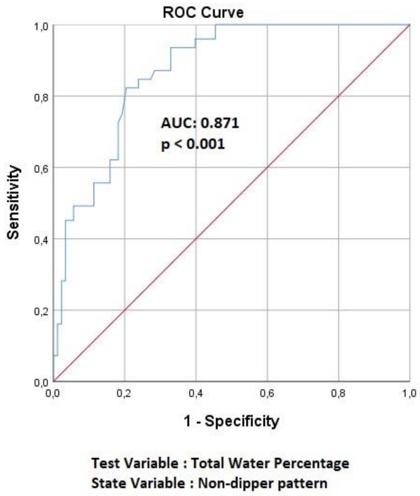

Figure 2. Receiver operating characteristic (ROC) curve of total body water percentage for predicting the non-dipper blood pressure pattern.

4. Discussion

The current study examined the correlation between total body water percentage and circadian blood pressure trends in prehypertensive individuals. The present study provides several important findings. First, the study population demonstrated a relatively high prevalence of the non-dipper blood pressure pattern, with more than half of the prehypertensive individuals in the study having this pattern. Second, individuals with a non-dipper blood pressure pattern had a significantly lower total body water percentage compared to those with a dipper pattern. Third, echocardiographic markers indicative of early structural cardiac remodeling, such as interventricular septal thickness and left ventricular end-diastolic diameter, exhibited substantial differences between the two groups. Furthermore, logistic regression analysis showed that the percentage of total body water, the thickness of the interventricular septum, and the end-diastolic diameter of the left ventricle were all independent factors that might predict the non-dipper blood pressure phenotype (Table 2).

Circadian variation in blood pressure is a well-established physiological phenomenon that plays a critical role in maintaining cardiovascular homeostasis. Under normal conditions, arterial blood pressure decreases during nocturnal sleep by approximately 10–20 percent, a pattern commonly referred to as the “dipping phenomenon.” Individuals who do not exhibit this normal nocturnal decline in blood pressure are classified as “non-dippers.” This unusual circadian pattern has been linked to higher rates of heart disease and death (18, 19). Several investigations have shown that the non-dipper phenotype is linked to harm to target organs, such as left ventricular hypertrophy, kidney problems, and cerebrovascular illness (20, 21). Also, it has been established that the size of the drop in blood pressure at night is linked to a lower chance of death from cardiovascular disease. This means that even minor drops in blood pressure at night may greatly raise the risk of cardiovascular disease (22).

In this study, approximately 58.6 percent of prehypertensive individuals exhibited a non-dipper pattern, which is consistent with previous reports suggesting that circadian blood pressure abnormalities may already be present in the early stages of blood pressure dysregulation. Table 1 shows that the clinical and laboratory features of the dipper and non-dipper groups were mostly the same. This suggests that the differences in circadian blood pressure patterns are not likely to be explained only by traditional cardiovascular risk factors. Physiological characteristics associated with fluid balance and heart anatomy may have a more significant influence on circadian blood pressure fluctuation.

One of the principal findings of the present study was the significantly lower total body water percentage observed in individuals exhibiting a non-dipper blood pressure pattern compared with those demonstrating a dipper pattern. This finding suggests that alterations in body fluid distribution, rather than absolute fluid volume, may play a critical role in the pathophysiology of circadian blood pressure dysregulation. The total body water weight did not show significant differences between the groups; nevertheless, the relative proportion of body water was markedly lower in non-dipper individuals (Table 1). ROC curve analysis demonstrated that total body water percentage exhibited strong discriminative performance for identifying the non-dipper blood pressure pattern, with an AUC of 0.871. (Figure 2). These results indicate that changes in the distribution of bodily fluids, rather than the total fluid volume, may play a role in aberrant circadian blood pressure under control. Several pathophysiological mechanisms may explain the observed association between hydration status and circadian blood pressure patterns. First, fluid redistribution plays a key role in nocturnal hemodynamics. During the daytime, a significant proportion of body fluid accumulates in the lower extremities due to gravitational forces. This fluid is moved back into the central circulation while you sleep. Impaired fluid redistribution may thus modify intravascular volume dynamics and lead to aberrant nocturnal blood pressure regulation. Second, changes in water levels may affect how the autonomic nervous system works. Non-dipper individuals have demonstrated heightened sympathetic nervous system activity during nocturnal hours, potentially mitigating the typical nocturnal decrease in blood pressure (23). Third, an aberrant fluid balance may affect sodium handling and pressure natriuresis processes, which are strongly related to the regulation of blood pressure throughout the day (24).

In addition to hydration-related findings, echocardiographic parameters provided further insight into cardiovascular structural alterations associated with circadian blood pressure patterns. The echocardiographic findings of this study provide important knowledge about the relationship of circadian blood pressure profiles with cardiac morphology. Non-dipper patients had a markedly greater left ventricular end-diastolic diameter and an elevated interventricular septal thickness in comparison to dipper individuals (Table 1). These results could indicate early structural cardiac remodeling linked to irregular blood pressure patterns. Previous research has shown that high blood pressure at night for a long time might cause the myocardium to be exposed to more afterload for a longer time, which can cause left ventricular hypertrophy and changes in the structure of the heart (19, 25, 26). The existence of these structural alterations in prehypertensive individuals indicates that atypical circadian blood pressure patterns may serve as an early indicator of cardiovascular risk.

Logistic regression analysis further confirmed the independent association between total body water percentage and the non-dipper blood pressure pattern. In the univariable analysis, various characteristics such as interventricular septal thickness, left ventricular end-diastolic diameter, E wave velocity, and total body water percentage exhibited significant associations with the occurrence of a non-dipper pattern. In the multivariable model, though, the total body water percentage was still a strong independent predictor of the non-dipper phenotype (Table 2). These findings suggest that the makeup of body fluids may have something to do with how blood pressure changes over the course of a day.

From a clinical perspective, the results of this study indicate that hydration status may serve as an additional physiological component affecting diurnal blood pressure fluctuation. Bioelectrical impedance analysis is an easy and non-invasive way to check body composition and hydration levels. Regular evaluation of bodily fluid content may assist in identifying persons at heightened risk of atypical circadian blood pressure trends. Early identification of the non-dipper phenotype is clinically important because this phenotype has been linked to a higher risk of heart problems, such as heart attacks, strokes, and chronic kidney disease (20, 22). These findings highlight the potential role of hydration status as a modifiable factor in the assessment of circadian blood pressure abnormalities. Moreover, these data suggest that interventions aimed at hydration status and fluid balance may affect circadian blood pressure control. Lifestyle modifications, including enhanced hydration, sodium limitation, consistent physical exercise, and weight management, may enhance circadian blood pressure rhythms. Nonetheless, prospective investigations are essential to ascertain whether alterations in hydration status can directly affect diurnal blood pressure fluctuation (6).

In summary, the findings of this study indicate that body fluid content may have an unacknowledged influence on circadian blood pressure regulation. The found correlation between diminished total body water percentage and the non-dipper blood pressure pattern offers novel insights into the biology of early blood pressure dysregulation. These results bolster the concept that modifications in fluid balance may lead to atypical circadian blood pressure patterns prior to the onset of overt hypertension.

Importantly, the study population was defined within blood pressure ranges that correspond to contemporary guideline classifications, particularly the "high-normal" and "elevated blood pressure" categories described in recent ESC and international recommendations. This alignment supports the clinical relevance and applicability of the present findings within current guideline frameworks. Moreover, the primary analyses were based on continuous blood pressure measurements and circadian patterns rather than treatment thresholds, suggesting that the findings remain robust irrespective of classification terminology.

This study has several limitations. First, the retrospective cross-sectional design precludes causal inference. Second, the study was conducted at a single center, which may limit generalizability. Third, body fluid composition was assessed at a single time point, and dynamic changes were not evaluated. Additionally, several potential confounding factors, including dietary sodium intake, hydration habits, sleep quality, and obstructive sleep apnea, were not systematically assessed. Therefore, these variables cannot be completely excluded.

5. Conclusion

In conclusion, this study demonstrates a significant association between total body water percentage and circadian blood pressure patterns in prehypertensive individuals. Lower total body water percentage was independently associated with a non-dipper blood pressure pattern in prehypertensive individuals. These findings suggest that alterations in hydration status may contribute to early circadian blood pressure dysregulation. Assessment of total body water percentage may represent a simple and non-invasive approach for identifying individuals at increased cardiovascular risk. Further prospective studies are required to confirm these findings.

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