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The relationship between nocturnal blood pressure drop and body composition indices among hypertensive patients

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Abstract

Among hypertensive subjects, the lack of physiological blood pressure drop as part of diurnal blood pressure variations is termed as non-dipper blood pressure. Herein, we investigated the relationship between hypertension character and body composition indices. This study included a total of 104 patients (54 M, mean age: 47.6 ± 12.1 years). Patients' heights, weights, and waist and hip circumferences were measured, and body composition indices were calculated. All patients' office blood pressure measurements and 24-hour ambulatory blood pressure readings were recorded. A blood pressure drop of at least 10% compared with daytime blood pressure readings is called dipper blood pressure, while a drop of less than 10% is termed as non-dipper blood pressure. Based on ambulatory blood pressure readings, the patients were grouped into Group 1 (dipper pattern; 51 pts, 34 M, mean age 45.6 ± 12.3) and Group 2 (non-dipper pattern, 53 pts; 20 M, mean age 49.6 ± 11.6). The proportion of females and smokers were significantly lower in Group 1 than Group 2. BRI, BAI, waist-to-height ratio, and waist circumference were significantly higher in Group 2 than Group 1. There were significant positive correlations between body roundness index (BRI), body adiposity index (BAI), waist-to-weight ratio, and WC and nocturnal mean systolic and diastolic blood pressure readings. Percent systolic nocturnal drop was significantly correlated with waist-to-height ratio, BAI, and BRI. Similarly, percent diastolic nocturnal drop and waist-to-height ratio, BAI, and BRI were correlated. In conclusion, the relatively new body composition indices, namely BRI and BAI, are more closely related to nocturnal blood pressure readings among non-dipper subjects.

1 | INTRODUCTION

Hypertension is blood pressure elevation above normal limits or to a level that increases the risk of injury to the target organs such as the heart, brain, and kidneys.[1] Hypertension is among the most common causes of hospital admissions worldwide. Despite advanced modern treatment methods, hypertension is still not adequately controlled, and associated with considerably high morbidity and mortality rates.[2] Studies on normal subjects have shown that blood pressure rises to the highest levels in the morning, gradually drops during daytime, and dips at night.[3] A blood pressure drop of at least 10% compared with daytime blood pressure readings is called dipper blood pressure, while a drop of less than 10% is termed as non-dipper blood pressure.[3] It is well known that non-dipper pattern is associated with increased cardiovascular disease risk.[2,3] An association between increased body mass index and blood pressure elevation is well known, although its mechanism is yet to be fully clarified.[4-6]

Many measurement methods exist for determination of body fat distribution. Although body mass index (BMI) is the most widely used method, it has several flaws limiting its daily use. First of all, BMI cannot distinguish fat weight from muscle weight.[7,8] Moreover, WHO has stated that BMI is not suitable for assessing body fat distribution among different ethnicities.[9] In order to overcome this problem, waist circumference (WC) has been introduced. WC not only reflects abdominal fat deposition, but also body size.[10] Since the weaknesses of the available measures have been shown, several novel indices such as body shape index (BSI) and body roundness index (BRI) have been introduced, which show regional fat distribution more ideally.[10] Several studies have been conducted on the relationship between these new indices and blood pressure, and the findings seem to be contradictory. For example, in a study of Portuguese adolescents, BMI showed the expected positive association with blood pressure but the ABSI showed a negative association with blood pressure.[11] Another study conducted in China; BMI, WC, WHtR, and BRI, ABSI showed the weakest predictive value for hypertension in these population.[12] Cheung et al[13] found an association between development of hypertension and BSI. In another study conducted in China, Chang et al[14] concluded that ABSI, BMI, BRI, WC, and WHR were all associated with hypertension. ABSI showed the weakest association with hypertension, while BRI showed potential for use as an alternative obesity measure in assessment of hypertension.

In the present study, we investigated the relationship between hypertension character and the relatively newly introduced body composition indices like BRI and BSI.

2 | MATERIALS AND METHODS

2.1 | Patients

This study is a cross-sectional study conducted in a government hospital between June 2018 and June 2019. This study enrolled a total of 104 patients (54 M, 50 F, mean age: 47.6 ± 12.1 years) who were newly diagnosed with hypertension with ambulatory blood pressure monitorization and other studies after presenting to the Cardiology and Internal Diseases Departments. Subjects with pregnancy, history of obstructive sleep apnoea, acute infection, acute vascular event, malignancy, secondary hypertension, chronic renal failure, and uncontrolled thyroid dysfunction were excluded, as were those with resistant hypertension and those using medications elevating blood pressure. A detailed anamnesis (history of the complaints, medication, and past blood pressure measurements, etc) was taken from all patients, and all were physically examined in detail. Blood pressure was measured with a sphygmomanometer (ERKA perfect aneroid sphygmomanometer, Germany), and heart rate was recorded in sitting position after resting for 5 minutes. The participants were advised to avoid caffeinated drinks and exercise for at least 30 minutes before the measurement. Blood pressures were measured from left arm. During the measurement, each participant was seated with their tested arm supported at the level of the heart. The mean of 3 BP measurements was calculated and used in all analyses. Hypertension is defined as office SBP values ≥140 mm Hg and/or diastolic BP (DBP) values ≥90 mm Hg according to European Society of Cardiology 2018 hypertension guidelines.[15] The weight of the participants' was measured in light-weight clothing and without shoes. Patients' body weight was measured in kilograms, body height in meters, and waist and hip circumferences in centimeters as defined below. Patients' fasting blood glucose, total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), triglyceride, urea, creatinine, aspartate aminotransferase (AST), alanine transaminase (ALT), sodium and potassium levels were measured from venous blood samples after 8 hours of fasting. All patients underwent transthoracic echocardiography and 24-hour ambulatory blood pressure monitoring. All patients were provided with detailed information about the study, and they gave written informed consent. The local ethics committee approved the study.

2.2 | Body composition indices

Measurements were measured at the umbilicus using a non-elastic tape (to the nearest 0.1 cm).

Waist circumference: measured from the level of umbilicus and both subcostal regions, with the patient in upright position and both arms open.[16]

Hip circumference: measured from the symphysis pubis anteriorly and the most prominent part of the gluteal region posteriorly.[16]

Waist-to-height ratio: calculated by dividing WC in centimeters by height in centimeters.[16]

Waist-to-hip ratio: calculated by dividing WC in centimeters by hip circumference in centimeters.[16]

BMI: Body mass index—calculated by dividing body weight in kilograms by the square of body height in meters (kg/m^2).[16]

BSI: Body shape index—calculated with WC in centimeters, BMI, and body height in centimeters, using the formula WC/ BMI^2 × height$^{1/2}$.[17]

BRI: Body roundness index—calculated with WC in centimeters and body height in centimeters using the following formula below[18]:

$$364.2 - 365.5 \times \sqrt{1 - \left[\left(\mathrm{WC} / (2\pi)\ 2\right) / \left(0.5 \times \mathrm{Height}\right)\ 2\right]}$$

BAI: Body adiposity index—calculated with hip circumference in centimeters and body height in meters using the formula below[19]:

$$(\text{hip circumference} / \left[\text{height}^{1.5}\right] - 18.$$

2.3 | Transthoracic echocardiography

Echocardiogram procedures were performed using a Philips EPIQ 7 device (Philips Healthcare). A 2.5 MHz probe was used for the Doppler measurements, and a 2.5-3.5 MHz probe was used for tissue Doppler measurements. Measurements were calculated from 3 cardiac cycles. Left ventricle (LV) dimensions and wall thickness were obtained from the parasternal long axis with an M-mode cursor positioned just beyond the mitral leaflet tips, perpendicular to the long axis of the ventricle. LV end-diastolic diameter and end-systolic diameter and thicknesses of the interventricular septum and posterior wall of the left ventricle were measured. LV ejection fraction (LVEF) was estimated by Simpson's rule. Mitral inflow velocities were evaluated by pulse-wave Doppler with the sample volume placed at the tip of the mitral leaflets from the apical 4-chamber view. Using the average of 3 beats, diastolic peak early (E), peak late transmitral flow velocity (A), peak E to peak A velocities (E/A), and deceleration time of peak E velocity (EDT) were measured. Isovolumic contraction time (ICT), isovolumic relaxation time (IVRT), and ejection time (ET) were also measured. Myocardial performance index was measured with the following formula (IVRT + ICT/ET). Tissue Doppler velocities (Sm, Em, Am) were measured from lateral, septal and tricuspid annuli.[20]

2.4 | Ambulatory blood pressure monitoring

Twenty-four hour blood pressure monitoring was performed with a portable digital recorder (BPlab Blood pressure monitor, BPLAB Standart) and placing an appropriately sized cuff to left upper arm. The device was set to perform blood pressure measurements every 15 minutes during daytime and every 30 minutes between 00:00 at night and 08:00 in the morning. The patients were asked to continue their normal daily activities, to avoid heavy exercise, and to remain still during blood pressure measurements. The default setting for daytime (07:00-23:00) and nighttime (23:00-07:00) hours was modified appropriately based on the patient's feedback. A nighttime blood pressure drop of at least 10% was labeled as dipper pattern and a drop of less than 10% as non-dipper pattern.[21,22]

2.5 | Statistical analysis

The study data were analyzed using SPSS 22.0 software package. The numerical variables were expressed as mean ± standard deviation and non-normal distributed variables with median (25th percentile-75th percentile). Categoric variables were expressed as frequency (n) and percentage (%). Inter-group differences for categoric variables were tested using chi-square test or, when the assumptions for chi-square test were unmet, Fisher's exact test. The normality of distribution of numerical variables was tested with Kolmogorov-Smirnov test. The comparison of continuous variables between two independent groups was performed with independent samples *t* test when the parametric test assumptions were met, and with Mann-Whitney *U* test when the parametric test assumptions were unmet. The Spearman correlation analysis was used to evaluate the relationship between body composition indices and the ambulatory blood pressure recording values. Linear regression analysis was performed to determine whether potential confounders had an effect on the results. A *P* value of less than .05 was considered statistically significant.

3 | RESULTS

Based on ambulatory blood pressure readings, patients were grouped into Group 1 (dipper pattern; 51 pts, 34 M, mean age 45.6 ± 12.3) and Group 2 (non-dipper pattern, 53 pts; 20 M, mean age 49.6 ± 11.6). Table 1 shows the comparison of demographic variables, admission blood pressure measurements, and laboratory findings between the study groups. SBP and DBP in group 2 were significantly higher than in group 1 (138.6 ± 14.2 mm Hg vs 146.6 ± 12.1 mm Hg; *P* = .003, 81.8 ± 10.9 mm Hg vs 86.8 ± 8.6 mm Hg; *P* = .01, respectively). The percentages of female subjects and the smokers were significantly lower in Group 1 than Group 2 (Table 1). Laboratory findings were similar between the study groups (Table 1). Table 2 shows body composition indices and Table 3 blood pressure readings. BRI, BAI, waist-to-hip ratio, and HC were significantly higher in Group 2 (Table 2). When we compare the body composition indices of both men and women of each group among themselves, BRI, BAI, waist-to-height ratio, WC and HC were significantly higher in Group 2 men compared with group 1 men (5.76 ± 1.93 vs 4.47 ± 1.23, *P* = .001; 30.6 ± 5.5 vs 26.6 ± 4.3, *P* = .004; 0.61 ± 0.08 vs 0.55 ± 0.06, *P* = .04; 105.3 ± 15.6 vs 97.3 ± 9.7, *P* = .02; 110.4 ± 11.7 vs 101.9 ± 16.9, *P* = .05 respectively). BRI, BAI, and HC were significantly higher in Group 2 women compared with Group 1 women (5.76 ± 1.93 vs 4.53 ± 1.40, *P* = .02; 38.4 ± 6.3 vs 33.4 ± 6.9, *P* = .01; 113.0 ± 10.3 vs 105.3 ± 11.3, respectively).

TABLE 1 Demographic and laboratory features of the groups

	Group 1 (n = 51)	Group 2 (n = 53)	*P*
Age (y)	45.6 ± 12.3	49.6 ± 11.6	.10
Gender (F)	17	33	**.003**
Systolic blood pressure (mm Hg)	138.6 ± 14.2	146.6 ± 12.1	**.003**
Diastolic blood pressure (mm Hg)	81.8 ± 10.9	86.8 ± 8.6	**.01**
Heart rate (beat/min)	84.5 ± 8.8	84.3 ± 8.9	.88
Diabetes mellitus (n)	8	9	.85
Family history of CAD (n)	24	19	.25
Smoking (n)	13	25	**.02**
Glucose (mg/dL)	101.9 ± 27.8	110.3 ± 33.6	.18
Total cholesterol (mg/dL)	196.9 ± 75.2	217.4 ± 50.0	.15
Triglyceride (mg/dL)	190.9 ± 103.6	166.4 ± 131.4	.35
LDL cholesterol (mg/dL)	131.1 ± 35.0	140.0 ± 42.9	.30
HDL cholesterol (mg/dL)	43.7 ± 11.2	44.6 ± 10.1	.71
Urea (mg/dL)	29.0 ± 8.8	29.2 ± 7.8	.90
Creatinine (mg/dL)	0.82 ± 0.45	0.73 ± 0.13	.16
Sodium (mEq/L)	139.9 ± 2.2	140.1 ± 2.2	.62
Potassium (mEq/L)	4.40 ± 0.33	4.41 ± 0.34	.85
AST (mg/dL)	24.2 ± 11.7	22.3 ± 9.7	.39
ALT (mg/dL)	29.0 ± 20.7	24.1 ± 11.2	.15

Abbreviations: ALT, alanine transaminase; AST, aspartate transaminase; CAD, coronary artery disease; F, female; HDL, high-density lipoprotein; LDL, low-density lipoprotein.
The significance of bold values are $p < .01$, $p < .05$.

TABLE 2 Comparison of the body composition parameters between the groups

	Group 1 (n = 51)	Group 2 (n = 53)	P
BMI (kg/m^2)	29.9 ± 8.5	31.2 ± 5.5	.33
WC (cm)	96.8 ± 9.6	100.9 ± 13.7	.08
HC (cm)	103.1 ± 15.2	112.0 ± 10.8	.001
Waist-to-hip ratio	0.92 ± 0.05	0.89 ± 0.07	.09
Waist-to-height ratio	0.56 ± 0.06	0.61 ± 0.09	.001
BSI	0.078 ± 0.005	0.079 ± 0.004	.64
BRI	4.74 ± 1.33	5.90 ± 2.00	**.001**
BAI (%)	28.8 ± 6.1	35.4 ± 7.0	<.001

Abbreviations: BAI, body adiposity index; BMI, body mass index; BRI, body roundness index; BSI, body shape index; HC, hip circumference; WC, waist circumference.

The significance of bold values are $p < .001$.

TABLE 3 Comparison of ambulatory blood pressure measurements between the groups

	Group 1 (n = 51)	Group 2 (n = 53)	P
Mean daytime systolic BP (mm Hg)	134.1 ± 14.5	132.5 ± 16.9	.60
Mean daytime diastolic BP (mm Hg)	84.8 ± 8.6	80.4 ± 9.3	.01
Mean night systolic BP (mm Hg)	114.9 ± 12.0	129.1 ± 16.5	<.001
Mean night diastolic BP (mm Hg)	70.6 ± 7.3	76.8 ± 10.1	.001
24 h max BP (mm Hg)	178.8 ± 26.6	175.6 ± 29.0	.56
24 h min BP (mm Hg)	94.3 ± 11.6	99.9 ± 17.9	.05
Mean BP (mm Hg)	100.7 ± 10.1	99.2 ± 13.0	.51
% nocturnal decrease systolic (mm Hg)	15.1 ± 3.4	2.5 ± 5.2	<.001
% nocturnal decrease diastolic (mm Hg)	15.7 ± 4.2	2.4 ± 6.1	<.001
Mean pulse pressure (mm Hg)	48.2 ± 11.8	49.0 ± 15.1	.78

Abbreviation: BP, Blood pressure.

Among echocardiographic measurements, aortic diameter, interventricular septal thicknesses, and posterior left ventricular wall thickness were significantly greater in Group 2 than Group 1 (2.80 ± 0.47 vs 2.61 ± 0.27 cm, $P = .02$; 1.11 ± 0.17 vs 1.10 ± 0.15 cm, $P = .02$; 1.09 ± 0.37 vs 0.97 ± 0.14 cm, $P = .04$, respectively).

An analysis of the relationship between office blood pressure and body composition indices revealed that the former was correlated with all indices except for BMI. A Spearman's correlation analysis between body composition indices found to be significantly different across the groups and nocturnal blood pressure measurements showed significant positive correlations between BRI, BAI, waist-to-height ratio, and WC and mean nocturnal systolic and diastolic blood pressure readings (Table 4). There were significant correlations between percent systolic nocturnal blood pressure drop and waist-to-height ratio, BAI, and BRI (rho = −0.27; $P = .006$, rho = −0.40; $P < .001$, rho = −0.26; $P = .009$, respectively). There were no correlation between the ambulatory holter parameters and BMI. Similarly, there were significant correlations between percent diastolic nocturnal blood pressure drop and waist-to-height ratio, BAI, and BRI (rho = −0.33; $P = .001$, rho = −0.45; $P < .001$, rho = −0.32; $P = .001$, respectively). Although there were correlations between interventricular septal thickness and all body composition indices, the correlation was found between waist-to-height ratio and BRI (rho = 0.32, $P = .001$, rho = 0.33, $P < .001$, respectively). There was no significant difference in the correlation coefficient when divided into men and women.

TABLE 4 Spearman's correlation analysis between BAI, BAI, WC, WC-to-height ratio, and mean nighttime blood pressures

	Rho	P
Mean night systolic BP		
BRI	0.43	<.001
BAI	0.40	<.001
WC	0.30	.002
WC-to-height ratio	0.44	<.001
BMI	0.20	.113
Mean night diastolic BP		
BRI	0.28	.004
BAI	0.21	.03
WC	0.22	.02
WC-to-height ratio	0.29	.002
BMI	0.19	.07

Abbreviations: BAI, body adiposity index; BMI, body mass index; BP, blood pressure; BRI, body roundness index; WC, waist circumference.

Linear regression analysis was performed to determine whether age, smoking status, and systolic and diastolic blood pressure had an effect on the results and no significant effect was found.

4 | DISCUSSION

The basic result of our study is that a non-dipping pattern was closely related to relatively newly introduced body composition indices, with BRI and BAI being proportional to nocturnal blood pressure readings.

Ambulatory blood pressure readings have indicated a condition with limited physiological blood pressure drop at night, which is termed as non-dipper blood pressure pattern. This abnormal diurnal blood pressure changes in non-dippers have been linked to a greater incidence of cardiovascular target organ injury and adverse cardiovascular events as compared to dippers.[21-24]

Although several factors like daytime inactivity and poor sleep quality have been held responsible for the non-dipper status, some contradictory reports exist.[25] Excess weight is thought to increase blood pressure by causing excessive sodium reabsorption from the kidneys, impaired renal natriuresis, and increased extracellular fluid volume.[26,27] Population studies performed so far in various societies worldwide have proven that blood pressure shows close correlation with anthropometric indices such as BMI, WC, and waist-to-hip ratio.[28,29] In our study, we demonstrated a weak, albeit significant, correlation between blood pressure readings, and body composition indices. Furthermore, we demonstrated that, in addition to WC, newer body composition indices such as BRI, BAI, and waist-to-height ratio were especially related to nocturnal blood pressure. We failed to show a similar relationship between BMI and nocturnal blood pressure readings. These findings suggest that body composition indices are closely related to a non-dipper blood pressure pattern.

BMI is used as an index of inadequate or excessive nutrition. It gives weight relative to height, and its costless calculation has been considered an advantage. However, studies have demonstrated that although a higher BMI is related to an increased risk of DM and metabolic syndrome,[30] it cannot differentiate relative amounts of fatty and fatless masses since it is generally a measure of inadequate or excess weight.[31,32] Moreover, BMI cannot monitor changes both in children and adults.[33] WC has begun to be used as an alternative and was even suggested to be a potential predictor of mortality in a pooled analysis involving 65.000 adults.[34] Among subjects with BMIs ranging between 20 and 50 kg/m^2, a 5-cm increase in WC was shown to be related to a higher mortality in both men and women.[35] However, WC, as BMI, is flawed by a J curve in mortality prediction.[36] Therefore, a need has arisen for novel body composition indices. Body shape index (BSI) and BAI are relatively newly introduced indices, with BSI being shown to be more closely related to total mortality than BMI.[37] In addition to its clinical importance in familial obesity syndromes, BAI has also been shown to be related to insulin resistance among adults.[38] In a study, Deng et al[39] investigated the BMI and WC in their associations with prehypertension. They found that both BMI and WC were positively related to the prevalence of elevated BP but depend on age. Among younger subjects, WC seemed to be associated with hypertension among both men and women, but among older subjects the adjusted ORs for hypertension were modestly higher for WC than for BMI in men and modestly higher for BMI in women. Chang et al[14] investigated which anthropometric index is most related with hypertension in a rural population. They concluded that all indices are related with hypertension which BSI has the weakest relation. They also concluded BRI can be used for an alternative obesity measure in assessment of hypertension. In another study, Cheung et al[13] investigated the relation of BSI with incident hypertension. They found that BSI is less associated with incident hypertension than WC and BMI.

Chang et al[40] examined the role of BRI and BSI for defining left ventricular hypertrophy and demonstrated that BRI was closely related to left ventricular hypertrophy. Although they could not replicate the same result for BSI, they reported that BRI was superior than WC and BMI for defining left ventricular hypertrophy. In another study, Fujita et al[10] Investigated whether BSI could be a predictor of diabetes, hypertension, and dyslipidemia in the Japanese population in a retrospective cohort study involving multiple cases. They included baseline BMI, WC, and BSI values in the study and showed that each composition parameter had an effect on the development of diabetes, dyslipidemia, and hypertension. However, they concluded that the predictive power of BSI was significantly lower than that of BMI and WC. In our study, BSI was not different in non-dippers than dipper ones. Correlation analysis in BRI, BAI, WC, WC-to-height ratio is associated with blood pressure measurements at night, although we could not show this relationship in BSI. In another study in a particular ethnic group, Zhao et al[41] investigated the role of BSI and BRI relative to other indices for defining diabetes mellitus. They enrolled 15 078 subjects and demonstrated that among anthropometric indices, BMI had the least correlation. In another study, Zhang et al[42] sought for a relationship between BSI, BRI, and hyperuricemia. They demonstrated that BRI was closely related to hyperuricemia in obese women but not men, and to a greater degree than BMI and WC.

We demonstrated that all anthropometric indices were related to blood pressure readings. We also demonstrated that primarily BRI and BAI, but also WC and waist-to-height ratio, were correlated with nocturnal blood pressure readings among non-dippers who lacked physiological blood pressure drop at night. These data suggest that those anthropometric indices may be given a greater emphasis in follow-up and treatment of non-dipper subjects.

Study limitations: The main limitation of our study is small proportion of study groups. Our study is a cross-sectional study involving patients meeting the inclusion criteria at a certain time period. Some correlation analyses performed in the study were weak. We believe that those correlations would have been stronger if heavier patients with more advanced stages of hypertension had been enrolled. Because of the number of the tables were more, we did not perform a table between the body composition indices and echocardiographic measurements. The use of more sophisticated instruments to measure body composition (Bioimpedance, DEXA, …) would warrant greater validity to the study. Because of we do not have these techniques available in our institute, we could not use them. Basing the decision of the dipper or non-dipper pattern on a single ABPM measurement was one of the limitation of the study.

5 | CONCLUSION

In conclusion, the relatively newer body composition indices, that is, BRI and BAI, are more closely related to nocturnal blood pressure recordings among patients with non-dipper patterns. Considering that weight loss is an important treatment goal among hypertensive patients, BRI and BAI may have important implications for both follow-up and treatment of patients with a non-dipper pattern. Apart from BMI, these parameters may be used for the assessment of patients with hypertension.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Selcuk Candan and Turgut Karabag are responsible for the design of the study, the preparation of the first draft, and the completion of the whole manuscript. Ozlem Ozdemir Candan and Turgut Karabag have conducted the statistical analysis. All authors have read and given final approval of the version to be published.

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