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The Relationship of Bioimpedance and Biochemical Data with the Blood Pressure Response to Exercise

Biyoimpedans ve Biyokimyasal Verilerin Egzersize Bağlı Kan Basıncı Yanıtı ile İlişkisi

Ahmet Burak Dirim[1](İD), Halil Dönmez[2](İD), Serhat Karadağ[3](İD), Meltem Gürsu[4](İD), Nilay Şengül Samancı[2](İD), Sami Uzun[3](İD), Egemen Cebeci[3](İD), Ahmet Behlül[3](İD), Zeynep Karaali[2](İD), Savaş Öztürk[1](İD)

[1] Division of Nephrology, Department of Internal Medicine, İstanbul University Faculty of Medicine, İstanbul, Türkiye
[2] Clinic of Internal Medicine, Haseki Training and Research Hospital, İstanbul, Türkiye
[3] Division of Nephrology, Department of Internal Medicine, Haseki Training and Research Hospital, İstanbul, Türkiye
[4] Division of Nephrology, Department of Internal Medicine, Bezmialem Vakıf University, İstanbul, Türkiye

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**Ahmet Burak Dirim and Halil Dönmez are co-first authors.*

ABSTRACT

Introduction: *Most studies have shown that people who exhibit an exaggerated blood pressure (BP) response to exercise have a higher risk of development of hypertension (HT) in the future. In this study, we aimed to investigate the relationship between body volume compartments data and the BP response to exercise.*

Materials and Methods: *This study included patients who underwent an exercise stress test following the Bruce protocol in healthy, normotensive individuals. Demographic and routine laboratory data were recorded. Bioimpedance analysis (BIA) was performed on the patients, and an exercise stress test was conducted. BP was measured before and after the exercise stress test, including the recovery phase.*

Results: *A total of 67 patients (27 females and 40 males), with a mean age of 42.9 ± 10.4 years, were enrolled in the study. In multivariate analyzes, considering the parameters related to BP in univariate analyses, basal systolic blood pressure (SBP) and diastolic blood pressure (DBP) were only associated with serum uric acid levels (p= 0.008 and p= 0.034, respectively). Recovery phase SBP was associated with extracellular water (ECW), visceral fat mass (VFM), serum uric acid levels (p= 0.030, p= 0.047 and, p= 0.047, respectively). The differences between basal and post-exercise SBP were correlated with sex, soft lean mass (SLM), ECW, VFM, body cell mass (BCM) and serum sodium levels (p= 0.012, p= 0.028, p= 0.009, p= 0.005, and p= 0.018, respectively).*

Conclusion: *Serum uric acid levels are the most significant indicators of basal DBP and SBP in normotensive patients. ECW, VFM, SLM, BCM and serum*

Address for Correspondence/Yazışma Adresi

Ahmet Burak Dirim
Division of Nephrology, Department of Internal Medicine, İstanbul University Faculty of Medicine, İstanbul, Türkiye
e-mail: ahmetburakdirim@gmail.com

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sodium levels play a crucial role in the SBP response to exercise. These findings suggest that body composition may be an important factor in the pathogenesis of HT.

Key Words: *Exercise, blood pressure, bioimpedance*

ÖZ

Giriş: *Çalışmaların çoğu, egzersize abartılı kan basıncı (KB) yanıtı veren kişilerin gelecekte hipertansiyon (HT) geliştirme riskinin daha yüksek olduğunu göstermiştir. Bu çalışmada, vücut hacmi kompartmanları verileriyle egzersize bağlı (KB) yanıtı arasındaki ilişkinin araştırılması amaçlanmıştır.*

Materyal ve Metod: *Bu çalışmaya sağlıklı, normotansif bireylerde Bruce protokolünü takiben egzersiz stres testi yapılan hastalar dahil edildi. Demografik ve rutin laboratuvar verileri kaydedildi. Hastalara biyoempedans analizi (BIA) yapıldı ve egzersiz stres testi uygulandı. Egzersiz stres testinden önce ve sonra, toparlanma fazı da dahil olmak üzere kan basıncı ölçüldü.*

Bulgular: *Yaş ortalaması 42.9 ± 10.4 yıl olan toplam 67 hasta (27 kadın ve 40 erkek) çalışmaya dahil edildi. Çok değişkenli analizlerde, tek değişkenli analizlerde KB ile ilişkili parametreler dikkate alındığında bazal sistolik kan basıncı (SBP) ve diyastolik kan basıncı (DBP) sadece serum ürik asit düzeyleri ile ilişkiliydi (sırasıyla p= 0.008 ve p= 0.034). Toparlanma fazı SBP'si hücre dışı su (ECW), visseral yağ kütlesi (VFM) ve serum ürik asit seviyeleri ile ilişkiliydi (sırasıyla p= 0.030, p= 0.047 ve p= 0.047). Bazal ve egzersiz sonrası SBP arasındaki farklar cinsiyet, yumuşak yağsız kütle, ECW, VFM, vücut hücre kütlesi (BCM) ve serum sodyum seviyeleri ile ilişkiliydi (sırasıyla p= 0.012, p= 0.028, p= 0.009, p= 0.005 ve p= 0.018).*

Sonuç: *Serum ürik asit düzeyleri normotansif hastalarda bazal DBP ve SBP'nin en önemli göstergeleridir. ECW, VFM, SLM, BCM ve serum sodyum düzeyleri egzersize SBP yanıtında önemli bir rol oynamaktadır. Bu bulgular, vücut kompozisyonunun HT patogenezinde önemli bir faktör olabileceğini düşündürmektedir.*

Anahtar Kelimeler: *Egzersiz, kan basıncı, bioimpedans*

INTRODUCTION

Hypertension (HT) is an important health issue that affects a significant portion of the world's population and has been proven to be a risk factor for coronary heart disease, heart failure, stroke, peripheral arterial disease, and renal failure (1). Many studies have shown that individuals who exhibit excessive BP during exercise have an increased risk of developing HT in the future (2-9). Impaired vascular function, including abnormal endothelial function and arterial stiffness, is associated with BP response to exercise. This hypertensive response may be a key mechanism contributing to left ventricular hypertrophy and increased cardiovascular risk. Exercise electrocardiography (ECG) studies in HT have improved our ability to vascular endothelial disease before it becomes clinically evident (10). Gaining a deeper understanding of the factors influencing BP response to exercise is undoubtedly crucial.

One of the main mechanisms implicated in the development of HT is fluid overload (11). Obesity and visceral adiposity are also clinical conditions strongly associated with HT (12,13). Body fluid volume, particularly extracellular fluid volume, has been found to be closely associated with HT, especially in dialysis patients. Bioimpedance analysis (BIA) is an inexpensive, non-invasive, and portable method used to assess body composition. BIA can evaluate the volume and distribution of body fluid, fat distribution, muscle mass, and more. Numerous studies have explored the relationship between body fluid balance and HT, particularly in dialysis patients, where BIA measurements were used to assess the connection between HT and volume overload (14-16).

In this study, we aimed to examine the relationship between BIA and biochemical data with resting and exercise BP in normotensive patients.

MATERIALS and METHODS

Our study is a cross-sectional study that included patients admitted to our internal medicine and cardiology outpatient clinics who underwent exercise stress testing with no findings of ischemia. The study included patients without any comorbidities and excluded those under 18 and over 65 years of age. A total of 67 patients were included in the study. The European Society of Hypertension/European Society of Cardiology (ESH/ESC) 2018 HT guidelines were used to assess BP (17). Participants were divided into two groups: Group 1, consisting of patients with optimal and normal BP, and Group 2, consisting of patients with high-normal BP. An informed consent form was obtained from each patient, and the study

was initiated after approval from the local ethics committee of our hospital.

The patients' age, sex, smoking history, height, and weight were recorded. Body mass index (BMI) was calculated using the formula: [BMI= weight (kg) / (height $(m)^2$]. All patients underwent an exercise stress test using the Bruce protocol (18). A blood sample was obtained for biochemical analysis after 12 hours of fasting. BP measurements were taken before exercise, immediately after exercise, and at the fourth minute of the recovery phase. Finally, BIA was applied to all participants, and the data were recorded.

BP Measurement

Blood pressure was measured in a calm environment using the auscultatory method, with the arm supported at heart level and an appropriately sized cuff based on arm circumference. Measurements were taken from both arms, and the higher value was recorded. Korotkoff phase 1 was considered systolic blood pressure (SBP), while phase 5 was considered diastolic blood pressure (DBP). In addition to the measurement at rest (basal BP), BP was recorded at the end of the test (post-exercise BP) and at the fourth minute of the recovery phase of the exercise test (recovery BP). The difference between post-exercise systolic and diastolic BP values and their basal counterparts (ΔSBP and ΔDBP) was recorded.

Bioimpedance analysis

After 15 minutes of rest in the supine position and recording the participant's age, weight, and height, measurements of the body fluid compartments were performed using the BIA tool (Tanita SC 330 S), applying a 50 kHz current. The following values obtained by the BIA were recorded: total body water (TBW), extracellular water (ECW), intracellular water (ICW), fat mass (FM), fat-free mass (FFM), muscle mass (MM), mineral mass (MIM), bone mass (BM), visceral fat mass (VFM), body cell mass (BCM), soft lean mass (SLM), skeletal muscle mass (SMM), protein mass (PM), and basal metabolic rate (BMR).

Exercise stress test

A maximal exercise stress test was performed according to the Bruce protocol (until reaching 85% of the maximal heart rate), which is the most widely used test and involves gradually increasing the load (18). In this protocol, the test starts at 1.7 mph with a 10% incline, and both speed and incline increase gradually at each stage. This gradual progression allows for a significant increase in oxygen consumption. A 12-lead ECG was monitored at the start, during the test, and throughout the recovery period. The test was terminated when the maximum heart rate (220 - age in years) was reached, the workload could no longer be tolerated, or if any clinical indications arose.

Laboratory methods

Serum glucose (mg/dL), urea (mg/dL), creatinine (mg/dL), uric acid (mg/dL), cholesterol (mg/dL), triglycerides (mg/dL), sodium (meq/L), potassium (meq/L), calcium (mg/dL), phosphorus (mg/dL), albumin (g/dL), and alanine transaminase (ALT) (U/L) levels were measured from blood samples obtained after 8-12 hours of fasting. Serum glucose, urea, creatinine, uric acid, cholesterol, triglycerides, sodium, potassium, albumin, and ALT levels were measured according to the manufacturer's instructions using routine laboratory methods with the Siemens Advice 2400 auto analyzer.

Statistical Analysis

SPSS software (version 16.0, SPSS, Chicago, IL) was used for statistical analysis. Numerical data were expressed as mean ± standard deviation. Median, minimum, and maximum values were provided for variables with abnormal distribution. A paired sample t-test was used to compare parameter values at the beginning and end of the study. Paired Student's t-test or the Mann-Whitney U test was used for comparing the two groups. Correlations between normally distributed parameters were assessed using Pearson's correlation, while data with non-normal distribution were evaluated using Spearman's rho correlation test. Multivariate analyses were performed using regression analysis.

RESULTS

A total of 67 adults (27 females and 40 males) were included in the study. Mean age and BMI were 42.9 ± 10.4 years and 27.5 ± 4.1 kg/m^2, respectively. Of the patients, 27% were ex-smokers, 31.7% were current smokers, and 41.3% were non-smokers. Demographic, BP, BIA, and laboratory data of the patients are presented in Table 1. Thirty-four patients had optimal or normal BP (group 1), while 33 patients had high-normal BP (group 2).

Demographic data, BIA, laboratory data, and baseline and exercise-induced BP responses owere compa-

Table 1. Demographic, laboratory and bioimpedance data of the patients

	Mean ± SD
Age (year)	42.9 ± 10.4
Sex (female/male)	27/40
BMI (kg/m²)	27.5 ± 4.1
Basal SBP	126.2 ± 8.6
Basal DBP	80.2 ± 7.0
Post exercise SBP	158.4 ± 27.2
Post exercise DBP	84.0 ± 10.2
ΔSBP	32.2 ± 23.9
ΔDBP	3.7 ± 10.9
Recovery SBP	133.8 ± 14.2
Recovery DBP	83.8 ± 8.6
FM (kg)	21.3 ± 8.4
VFM (kg)	8.1 ± 3.6
FFM (kg)	56.2 ± 10.6
MM (kg)	53.4 ± 10.0
SLM (kg)	52.5 ± 9.5
BCM (kg)	37.9 ± 7.1
SMM (kg)	31.9 ± 5.8
PM (kg)	12.9 ± 2.8
MIM (kg)	4.0 ± 1.1
BM (kg)	2.8 ± 0.5
TBW (kg)	39.8 ± 7.1
ICW (kg)	23.8 ± 4.3
ECW (kg)	15.7 ± 2.8
BMR (kcal)	1674 ± 293
Glucose (mg/dL)	90.9 ± 9.3
Urea (mg/dL)	28.0 ± 7.5
Creatinine (mg/dL)	0.79 ± 0.17
Uric acid	4.9 ± 1.1
Albumin (g/dL)	4.5 ± 0.2
ALT (U/l)	23.0 ± 12.1
Triglyceride (mg/dL)	138.9 ± 82.2
HDL cholesterol (mg/dL)	46.7 ± 9.2
LDL cholesterol (mg/dL)	130.4 ± 36.2
Sodium (mmol/l)	140.6 ± 2.7
Potasium (mmol/l)	4.5 ± 0.4
Calcium (mg/dL)	9.4 ± 0.4
Phosphate (mg/dL)	3.5 ± 0.7
hsCRP (mg/dL)	3.1 ± 3.1

SD: Standart deviation, BMI: Body mass index, SBP: Systolic bloood pressure, DBP: Diastolic blood pressure, ΔSBP: Post exercise SBP-basal SBP, ΔSBP: Post exercise DBP-basal DBP, FM: Fat mass, VFM: Visceral fat mass, FFM: Fat free mass, MM: Muscle mass, SLM: Soft lean mass, BCM: Body cell mass, SMM: Skelatal muscle mass, PM: Protein mass, MIM: Mineral mass, BM: Bone mass, TBW: Total body water, ICW: Intracellular water, ECW: Extracellular water, BMR: Basal metabolism rate, ALT: Alanine aminotransferase, HDL: High density lipoprotein, LDL: Low density lipoprotein, hsCRP: High sensitive C reactive protein.

red between group 1 and group 2. The proportion of women was higher in group 1. Baseline SBP and DBP, post-exercise SBP, and recovery SBP and DBP were significantly lower in group 1, whereas the ΔDBP difference was significantly higher (Table 2). In terms of bioimpedance analysis, group 1 had significantly lower BMI, VFM, FFM, MM, SLM, TBW, BCM, SMM, PM, BM, ICW, and ECW compared to group 2 (Table 2).

When comparing laboratory data between patients in group 1 and group 2, group 1 had statistically lower levels of creatinine, uric acid, HDL cholesterol, and ALT (Table 2). The univariate correlation analysis between demographic data, bioimpedance data, and biochemical analysis with basal SBP, ΔSBP, and recovery SBP in patients is shown in Table 3.

Univariate analyses were conducted with baseline DBP correlation, and with age, BMI, TBW, FFM, MM, BM, VFM, ICW, ECW, BCM, SMM, PM, BMR, uric acid, and triglycerides, respectively (Supplemental Table). DBP and recovery DBP did not show a correlation with any BIA or laboratory data.

Multivariate analysis (Table 4): In the univariate analysis, in addition to age and sex, uric acid levels were the most significant variable in determining basal SBP in the pattern created from BMI, BMR, BM, ECW, BCM, FM, TBW, PM, VFM, uric acid levels, and HDL-cholesterol levels, all of which have a relationship with basal SBP.

In the univariate analysis, besides age and sex, uric acid levels emerged as the most significant variable in determining basal DBP, within a pattern formed by BMI, BMR, BM, ECW, BCM, TBW, PM, VFM, uric acid, and triglyceride levels, all of which are related to basal DBP.

Table 2. Comparison of age, sex, blood pressure, BIA and routine biochemistry data of the patients with normal and optimal (group 1) and high normal (group 2) blood pressure

	Group 1 (n= 34)	Group 2 (n= 33)	p
Age (year)	40.8 ± 11.1	44.9 ± 9.3	0.105
Sex (female/male)	18/16	9/24	**0.029**
BMI (kg/m²)	26.4 ± 4.4	28.6 ± 3.5	**0.028**
Basal SBP	119.4 ± 5.4	133.1 ± 4.9	**<0.001**
Basal DBP	75.6 ± 5.8	85 ± 4.5	**<0.001**
Post exercise SBP	147.6 ± 19.6	169.5 ± 29.5	**0.001**
Post exercise DBP	82.4 ± 9.9	85.5 ± 10.4	0.220
ΔSBP	28.1 ± 18.9	36.5 ± 27.8	0.160
ΔDBP	6.8 ± 11.8	0.5 ± 9.1	**0.022**
Recovery SBP	127.4 ± 12.1	140.4 ± 13.1	**<0.001**
Recovery DBP	81.2 ± 6.1	86.5 ± 10.0	**0.012**
FM (kg)	19.9 ± 8.3	22.6 ± 8.3	0.183
VFM (kg)	6.9 ± 3.1	9.3 ± 3.7	**0.005**
FFM (kg)	52.3 ± 10.5	60.0 ± 9.5	**0.003**
MM (kg)	49.8 ± 9.8	57.0 ± 9.0	**0.003**
SLM (kg)	49.1 ± 9.1	55.9 ± 8.9	**0.003**
BCM (kg)	35.5 ± 6.8	40.2 ± 6.7	**0.006**
SMM (kg)	29.9 ± 5.6	34.0 ± 5.4	**0.004**
PM (kg)	11.9 ± 2.7	13.8 ± 2.6	**0.007**
MIM (kg)	3.9 ± 1.4	4.1 ± 0.7	0.498
BM (kg)	2.7 ± 0.5	3.0 ± 0.4	**0.003**
TBW (kg)	37.4 ± 6.9	42.1 ± 6.4	0.06
ICW (kg)	22.3 ± 4.1	25.3 ± 4.0	**0.004**
ECW (kg)	14.7 ± 2.7	16.8 ± 2.5	**0.002**
BMR (kcal)	1569 ± 267	1778 ± 284	**0.003**
Glucose (mg/dL)	89.8 ± 8.1	92.1 ± 9.4	**0.355**
Urea (mg/dL)	27.0 ± 6.6	29.1 ± 8.4	**0.331**
Creatinine (mg/dL)	0.74 ± 0.16	0.83 ± 0.17	**0.038**
Uric acit (mg/dL)	4.3 ± 0.9	5.6 ± 0.9	**<0.001**
Albumin (g/dL)	4.5 ± 0.2	4.4 ± 0.2	**0.224**
Triglyceride (mg/dL)	118.6 ± 62.6	160.0 ± 95.3	**0.066**
LDL cholesterol (mg/dL)	125.6 ± 34.1	135.4 ± 38.3	**0.327**
HDL cholesterol (mg/dL)	48.9 ± 8.6	44.3 ± 9.3	**0.024**
ALT (U/l)	19.9 ± 11.1	26.3 ± 12.4	**0.021**
Sodium (mmol/l)	140.2 ± 2.8	141.0 ± 2.6	**0.277**
Potasium (mmol/l)	4.5 ± 0.4	4.6 ± 0.4	**0.245**
Calcium (mg/dL)	9.4 ± 0.4	9.4 ± 0.3	**0.998**

Table 2. Comparison of age, sex, blood pressure, BIA and routine biochemistry data of the patients with normal and optimal (group 1) and high normal (group 2) blood pressure (continue)

	Group 1 (n= 34)	Group 2 (n= 33)	p
Phosphate (mg/dL)	3.6 ± 0.7	3.5 ± 0.6	**0.591**
hsCRP (mg/dL)	3.0 ± 3.4	3.1 ± 2.8	**0.880**

BMI: Body mass index, SBP: Systolic bloood pressure, DBP: Diastolic blood pressure, ΔSBP: Post exercise SBP-baseline SBP, FM: Fat mass, TBW: Total body water, FFM: Fat free mass, MM: Muscle mass, BM: Bone mass, VFM: Visceral fat mass, ICW: Intracellular water, ECW: Extracellular water, BCM: Body cell mass, SLM: Soft lean mass, SMM: Skelatal muscle mass, PM: Protein mass, BMR: Basal metabolism rate, ALT: Alanine aminotransferase, HDL: High density lipoprotein, LDL: Low density lipoprotein, hsCRP: High sensitive C reactive protein.

Table 3. Univariate correlation analysis between SBP values and demographic data, bioimpedance data and routine biochemistry data in the patients

	Basal		Recovery		ΔSBP	
	r	p	r	p	r	p
Age (year)	0.164	0.185	0.079	0.527	0.222	0.071
BMI (kg/m^2)	**0.352**	**0.004**	**0.312**	**0.011**	**0.331**	**0.007**
FM (kg)	**0.269**	**0.029**	**0.243**	**0.049**	**0.315**	**0.010**
VFM (kg)	**0.381**	**0.002**	**0.321**	**0.009**	**0.394**	**0.001**
FFM (kg)	**0.374**	**0.002**	**0.346**	**0.004**	0.241	0.051
MM (kg)	**0.372**	**0.002**	**0.349**	**0.004**	**0.247**	**0.046**
SLM (kg)	**0.365**	**0.003**	**0.358**	**0.003**	**0.260**	**0.035**
BCM (kg)	**0.336**	**0.006**	**0.323**	**0.008**	**0.244**	**0.048**
SMM (kg)	**0.364**	**0.003**	**0.356**	**0.003**	**0.259**	**0.035**
PM (kg)	**0.306**	**0.012**	**0.256**	**0.038**	0.188	0.131
MIM						
BM (kg)	**0.370**	**0.002**	**0.357**	**0.003**	0.150	0.228
TBW (kg)	**0.355**	**0.003**	**0.379**	**0.002**	**0.284**	**0.021**
ICW (kg)	**0.364**	**0.003**	**0.355**	**0.003**	**0.259**	**0.036**
ECW (kg)	**0.416**	**0.001**	**0.422**	**<0.001**	**0.288**	**0.019**
BMR (kcal)	**0.377**	**0.002**	**0.364**	**0.003**	**0.261**	**0.035**
Glucose (mg/dL)	0.254	0.066	-0.048	0.732	-0.121	0.387
Urea (mg/dL)	0.141	0.315	0.030	0.831	-0.075	0.593
Creatinine (mg/dL)	0.144	0.303	0.126	0.367	0.054	0.699
Uric acid (mmol/l)	**0.527**	**<0.001**	**0.509**	**<0.001**	0.241	0.082
Albumin (g/dL)	-0.158	0.257	-0.028	0.840	-0.177	0.205
ALT (U/l)	0.234	0.092	**0.317**	**0.021**	0.158	0.260
Triglyceride (mg/dL)	0.233	0.094	0.215	0.121	**0.320**	**0.019**
HDL-cholesterol (mg/dL)	**-0.276**	**0.046**	**-0.330**	**0.016**	-0.143	0.306
LDL-cholesterol (mg/dL)	0.082	0.559	0.017	0.902	-0.050	0.723
Sodium (mmol/l)	0.167	0.233	-0.097	0.489	-0.307	0.025
Potasium (mmol/l)	0.244	0.078	0.082	0.561	-0.049	0.729
Calcium (mg/dL)	-0.074	0.601	-0.067	0.632	-0.109	0.438
Phosphate (mmol/l)	-0.091	0.516	-0.161	0.248	-0.081	0.565

BMI: Body mass index, SBP: Systolic bloood pressure, ΔSBP: Post exercise SBP-basal SBP, FM: Fat mass, VFM: Visceral fat mass, FFM: Fat free mass, MM: Muscle mass, SLM: Soft lean mass, BCM: Body cell mass, SMM: Skelatal muscle mass, PM: Protein mass, MIM: Mineral mass, BM: Bone mass, TBW: Total body water, ICW: Intracellular water, ECW: Extracellular water, BMR: Basal metabolism rate, ALT: Alanine aminotransferase, HDL: High density lipoprotein, LDL: Low density lipoprotein, hsCRP: High sensitive C reactive protein.

Supplemental Table. Univariate correlation analysis for baseline diastolic blood pressure with clinical, laboratory, and bioempedance data

Variable	Correlation (r)	p-value
Age	0.244	0.046
BMI	0.303	0.013
TBW	0.335	0.014
FFM	0.379	0.002
MM	0.374	0.002
BM	0.344	0.005
VFM	0.409	0.001
ICW	0.350	0.004
ECW	0.377	0.002
BCM	0.350	0.004
SMM	0.350	0.004
PM	0.344	0.005
BMR	0.362	0.003
Uric Acid	0.440	0.001
Triglycerides	0.302	0.028

BMI: Body mass index, TBW: Total body water, FFM: Fat free mass, MM: Muscle mass, BM: Bone mass, VFM: Visceral fat mass, ICW: Intracellular water, ECW: Extracellular water, BCM: Body cell mass, SMM: Skelatal muscle mass, PM: Protein mass, BMR: Basal metabolism rate.

For ΔSBP, the univariate analysis revealed that in addition to age and sex, SLM, ECW, VFM, BCM, and sodium levels were the most significant variables. This pattern was formed by BMI, BMR, SLM, BM, ECW, FM, TBW, FFM, BCM, serum sodium, and triglyceride levels, which are associated with ΔSBP.

When analyzing recovery SBP, ECW, VFM, and uric acid levels, alongside age and sex, were identified as the most significant variables. This pattern included BMI, BMR, BM, ECW, BCM, FM, TBW, PM, VFM, uric acid, HDL-cholesterol, and ALT levels, all of which are linked to recovery SBP.

Regarding the multivariate analysis, no parameters were found to be associated with recovery DBP or ΔDBP.

DISCUSSION

When compared to BMI, FFM, MM, BM, ICW, ECW, BCM, SLM, SMM, PM, and BMR, patients with optimal and normal BP had significantly lower values than those with high-normal BP, in our study. Regarding biochemical data, creatinine, uric acid, HDL-cholesterol, and ALT levels were significantly lower in patients with optimal and normal BP. Our paper highlighted that patients with high-normal BP, before the development of HT, showed differences in body composition, particularly in terms of fluid levels and visceral adiposity.

However, when all patients were considered as a single group in the multivariate analysis, uric acid levels were identified as the sole factor associated with basal SBP and DBP. No relationship was observed between SBP and DBP with any BIA or biochemical data. Uric acid also showed a significant relationship with recovery SBP in the multivariate analysis.

Table 4. Multivariate analyzes related to blood pressure measurements

		B	Beta	p
Basal SBP	Uric acid (mg/dL)	3.496	0.442	**0.008**
Basal DBP	Uric acid (mg/dL)	2.320	0.358	**0.034**
ΔSBP	Sex	-74.588	-1.533	**0.012**
	SLM (kg)	-28.420	-11.619	**0.028**
	ECW (kg)	38.356	4.573	**0.009**
	VFM (kg)	7.830	1.174	**0.010**
	Sodium (mmol/L)	-3.209	-0.344	**0.005**
	BCM (kg)	30.581	9.297	**0.018**
Recovery SBP	ECW (kg)	13.416	2.545	**0.030**
	VFM (kg)	-4.462	-1.062	**0.047**
	Uric acid (mg/dL)	4.964	0.354	**0.042**

SBP: Systolic bloood pressure, DBP: Diastolic blood pressure, ΔSBP: Post exercise SBP-basal SBP, VFM: Visceral fat mass, SLM: Soft lean mass, BCM: Body cell mass, ECW: Extracellular water.

Importantly, uric acid did not show any relationship with BP response to exercise. We interpret this finding as indicating that while uric acid levels are associated with resting BP, they do not influence the BP response to exercise.

Schultz et al. have suggested in their meta-analysis that an exaggerated BP response is an important risk factor for cardiovascular events and mortality (8). In a study conducted by Tsumura et al., it has been found that, in addition to the BP responses to exercise, the resting SBP and DBP values after the exercise test were associated with an increased risk of HT (9). Yokokawa et al. have demonstrated in their study that uric acid levels were higher in patients with HT compared to normotensive individuals, finding a positive correlation with both SBP and DBP (19). Another study has identified serum uric acid levels as an important predictor of SBP in prehypertensive patients (20). In an experimental study conducted in rats with metabolic syndrome, it has been shown that allopurinol, which lowers uric acid levels, reduced HT and proteinuria (21). Additionally, a double-blind placebo-controlled study in prehypertensive obese adolescents has shown that BP decreased significantly more in the group receiving urate-lowering therapy than in the placebo group (22). Although our study group and patient numbers differ from the studies mentioned above, we believe the relationship between BP and serum uric acid levels is meaningful for understanding the pathogenesis of HT.

In our study, univariate analysis revealed a positive correlation between ECW and post-exercise SBP, recovery SBP, and ΔSBP. A significant relationship was also found in the multivariate analysis. This suggests that as the amount of ECW increases, SBP rises with exercise. A study conducted in Türkiye found that ECW/height values were significantly correlated with SBP. However, this study was performed in patients with concomitant diseases (HT, diabetes, coronary artery disease, chronic obstructive lung disease, chronic renal disease) and healthy volunteers, and did not include an exercise test (23).

In contrast, our study showed no relationship between basal SBP and ECW, but there was a significant relationship between ECW and recovery SBP, as well as SBP response to exercise. The differences in our results can be attributed to the variations in the study groups, study design, and the number of participants. In our study, we focused on healthy, normotensive individuals without concomitant diseases and investigated the relationship between body composition and BP response to exercise.

Alvarez-Lara et al. have demonstrated that both TBW and ECW were significantly higher in hypertensive hemodialysis patients compared to normotensive patients in their study, which included 32 hemodialysis patients (14). Inal et al. have found that ECW levels were significantly higher in hypertensive peritoneal dialysis patients compared to normotensive individuals (15). In another study, it has been shown that the amount of ECW correlated with SBP and left ventricular mass index in hemodialysis patients. Moreover, in patients undergoing hemodialysis three times a week, it has been observed that switching to daily hemodialysis treatment led to reductions in BP values, left ventricular mass index, and the need for antihypertensive medications. This effect has been suggested to be related to a decrease in ECW content (16).

Both our study and the studies mentioned above are important in demonstrating the relationship between BP and extracellular fluid. In our study, the multivariate analysis showed that VFM was significantly correlated with recovery SBP and ΔSBP. These findings suggest that VFM could play a role in BP response to exercise, as it exhibited a positive correlation with increased SBP during exercise. Wang et al. have reported that excessive visceral fat is strongly associated with HT and the risk of prehypertension in a study with over ten thousand participants (13). In another study involving four thousand individuals, visceral fat index has been associated with BP, and it has been found to be significantly higher in the prehypertension group (24). In line with these findings, our study also revealed that VFM was significantly higher in patients with high-normal BP.

In this study, multivariate analysis revealed a significant relationship between ΔSBP and SLM. We interpret this result as indicating that exercise-induced muscle activity, along with the activity of other organs, may be one of the factors contributing to the increased systolic BP response during exercise.

BCM represents metabolically active cell mass in the body, responsible for oxygen consumption, carbon dioxide production, and energy expenditure (25). In a study on intensive care dialysis patients, it has been suggested that BCM values are more sensitive than FFM in assessing nutritional status in cases of severe hydration disturbances. This is because FFM measurements can be affected by hydration issues, such as

edema (26,27). In our study, ΔSBP was found to be associated with BCM in multivariate analyses, suggesting that metabolically active cells in the body may play an important role in the BP response to exercise.

We also found that serum sodium levels were significantly associated with ΔSBP. As a key cation in the ECW compartment, sodium plays a crucial role in determining ECW volume. These findings suggest that sodium levels are essential in the development of systolic BP response to exercise.

The limitations of our study include its cross-sectional design and small sample size. However, the study is highly significant in demonstrating the relationship between BP response to exercise, recovery BP after exercise, and body composition and biochemical parameters, which may serve as predictors for the future development of HT.

CONCLUSION

In normotensive patients, uric acid levels are the most significant indicator of basal SBP and DBP. ECW, VFM, SLM, BCM, and serum sodium levels play a crucial role in the systolic BP response to exercise. These findings suggest that body composition may play an important role in the pathogenesis of HT. Further studies are needed to fully understand the role of body composition in the pathogenesis of HT and for the creation of new therapeutic alternatives.

ETHICS COMMITTEE APPROVAL

This study was approved by the Haseki Training and Research Hospital (Decision no: 141, Date: 20.08.2014).

CONFLICT of INTEREST

No conflict of interest declared.

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Writing: ABD, HD, SÖ, SK, MG, SU, AB, NŞS

Review and Correction: MG, SK, SU, NŞS, EC, ZK, AB

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