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The Effect of Body Mass Index on Blood Pressure and Heart Rate Response During Treadmill Exercise Test in Non-diabetic Adults

Vücut Kitle İndeksinin Diyabeti Olmayan Yetişkinlerde Efor Testi Esnasında Gözlenen Kan Basıncı ve Kalp Hızına Olan Etkisi

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ABSTRACT

Introduction: Exaggerated blood pressure response to exercise is an independent risk of future hypertension (HT), and impaired heart rate (HR) response is a predictor of cardiovascular mortality and morbidity. Obesity is a risk factor for HT. This study aimed to evaluate the influence of body mass index (BMI) on systolic blood pressure (SBP) and HR during exercise treadmill test.
Methods: Data of 124 patients without diabetes who completed treadmill test with negative results were obtained from archives of the test unit. Patients were divided into three groups according to BMI; 18.5-24.9 (normal), 25-29.9 (overweight), and >30 (obese). Basal, 3rd and 6th minutes, peak exercise, 2nd minute of recovery phase SBP and HR values, and level changes (Δ) from the beginning were compared. A p-value of <0.05 was considered statistically significant.
Results: There was a difference in terms of mean SBP and ΔSBP among the three groups (p<0.05). The 6th minute and peak exercise difference was more apparent between the obese and normal groups (p<0.001). The overweight and obese group had significantly higher mean SBP and ΔSBP values than the normal group during the recovery phase (p=0.005 and <0.001, respectively). Analysis of HR revealed that the obese group had higher HR levels than the normal group in the 3rd and 6th minutes (p<0.001 and p=0.003, respectively) but no difference at the peak and recovery phases.
Conclusion: Office blood pressure measurements may underrecognize the hypertensive status during active daily life. Exercise tests can help identify particularly overweight or obese individuals with exaggerated blood pressure response to exercise and are, therefore, at risk of developing HT. In this way, these individuals can be directed to early exercise and diet programs.

Keywords: Body mass index, exercise test, blood pressure, heart rate

ÖZ

Amaç: Egzersize abartılı kan basıncı yanıtı, gelecekte hipertansiyon gelişimi için bağımsız bir risk oluştururken, bozulmuş kalp hızı (KH) yanıtı ise kardiyovasküler mortalite ve morbidite için bir belirleyici olarak kabul görmüştür. Obezite hipertansiyon için bir risk faktörüdür. Bu çalışmada vücut kitle indeksinin (VKİ) efor testi esnasında gözlenen sistolik kan basıncı (SKB) ve KH yanıtı üzerine etkisini değerlendirmeyi amaçladık.

Yöntemler: Efor testini negatif sonuçlarla tamamlayan 124 diyabetsiz hastanın verileri, test ünitesinin arşivlerinden elde edildi. Hastalar VKİ'ye göre üç gruba ayrıldı; 18,5-24,9 (normal), 25-29,9 (aşırı kilolu) ve >30 (obez). Bazal, 3., 6. dakika, zirve egzersiz, iyileşme fazı 2. dakika SKB ve KH değerleri ve başlangıca göre değişim miktarları (Δ) gruplar arasında karşılaştırıldı. P<0,05 istatistiksel olarak anlamlı kabul edildi.

Bulgular: Üç grup arasında ortalama SKB ve ΔSKB açısından istatistiksel olarak anlamlı fark mevcuttu (p<0,05). Altıncı dakika ve zirve egzersiz anında ortalama SKB ve ΔSKB açısından fark obez grupta daha belirgindi (p<0,001). Recovery fazında aşırı kilolu ve obez grubun normal gruba göre SKB ve ΔSKB ortalamaları normal gruba göre anlamlı olarak daha yüksekti (sırasıyla; p=0,005; p<0,001). KH analizinde obez grubun KH seviyeleri 3. ve 6. dakikalarda normal gruptan daha yüksekti (sırasıyla; p<0,001; p=0,003), ancak zirve ve iyileşme aşamasında fark bulunmadı.

Sonuç: Poliklinik kan basıncı ölçümleri, aktif günlük yaşam sırasında gelişen hipertansif durumu saptayamayabilir. Efor testi, egzersize aşırı hipertansif yanıt gösteren bu nedenle HT gelişme riski taşıyan aşırı kilolu veya obez bireylerin saptanmasında ayrıca bu bireylerin diyet ve egzersiz programlarına yönlendirilmesinde yardımcı olabilir.

Anahtar Kelimeler: Vücut kitle indeksi, efor testi, kan basıncı, kalp hızı

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Introduction

Hypertension (HT) is a leading risk factor for increased cardiovascular morbidity and mortality (1). In obesity, HT is three times more likely to be observed (2). Furthermore, according to the Framingham Heart study, body weight above 20% of the ideal weight increases HT probability by up to eight times (3). An exaggerated blood pressure response to moderate exercise is an indicator of cardiovascular risk and an independent risk of future HT (4,5). Increasing the heart rate (HR) is an immediate physiological response to exercise and after exercise cessation; HR is expected to return to resting values. HR response to a graded exercise test is a powerful predictor of cardiovascular mortality and morbidity (6,7). The standard graded exercise test is an easy and inexpensive tool that provides a wealth of information on the cardiovascular system (6). Bruce protocol treadmill test with increasing speed and level is a commonly used graded exercise test (8). Body mass index (BMI) is a historical strong predictor of metabolic risks and is used to differentiate between normal weight, overweight, and obese subjects by approximating adiposity and fat distribution in adults (9,10). The influence of BMI and obesity on blood pressure response and HR during and after exercise was demonstrated in various studies before (11-15).

Unlike previous studies, this retrospective study aimed to evaluate the changes in systolic blood pressure (SBP) and HR in acute exercise and exercise resting phase between non-diabetic normal weight, overweight, and obese adults whose treadmill testing was negative for ischemia.

Methods

In this retrospective study, patients who were referred to our center between September 2012 and February 2013 for a treadmill exercise test were searched from the records. Clinical properties and anthropometric measurements were obtained from the archives of the treadmill test unit and the hospital database. Patients with diabetes mellitus diagnosis or more than stage 1 HT [SBP >159 mmHg and diastolic blood pressure (DBP) >99 mmHg], according to JNC 7, were excluded (16). Treadmill exercise testing was initiated and reported based on the American College Cardiology/American Heart Association practice guidelines using a Bruce protocol modified by two warm-up stages (8,17). A total of 124 patients without diabetes who completed the test with negative results for ischemia were enrolled in the study. Patients were told to take their anti-hypertensive medications at their regular schedule. During the test, patients were questioned every 2 min for symptoms, and the HR, blood pressure, and 12-lead electrocardiogram were recorded at baseline, end of each stage, and peak exercise. All patients reached the target HR (85% of 220 age) without ischemic symptoms or electrocardiogram changes.

Patients were divided into three groups according to their BMI: normal group 1 (18.5-24.9), overweight group 2 (25-29.9), and obese group 3 (>30). SBP and HR values were obtained from our database program at the beginning, 3rd and 6th minutes, peak of exercise, and 2nd minute of recovery. The mean SBP and HR levels and level changes (delta: Δ) from the basal values were compared between the three groups.

The study protocol has been approved by the University of Health Sciences Turkey, İstanbul Training and Research Hospital Local Hospital Ethics Committee (approval number: 237, date: 22.02.2013), and written informed consent was obtained from all patients.

Statistical Analysis

Numerical parameters were reported as mean ± standard deviation and categorical variables as percentage (%). In comparison, parametric or non-parametric statistical methods were used depending on whether the variable was normally distributed or not. One-Way analysis of variance and Tukey honest significant difference were used as a post-hoc test in comparison between the three groups in numerical parameters showing normal distribution. Chi-square statistics were used to compare categorical variables. Statistical analysis was performed using SPSS v.12.0. A p-value of <0.05 was considered statistically significant.

Results

Baseline characteristics of patients are summarized in Table 1. All three groups were well matched with respect to age, gender, and mean HR and SBP at the beginning, and all groups reached the target HR percentage at peak exercise. The percentages of stage 1 HT among groups were similar

Table 1. Baseline characteristics of patients

	Total no of patients	Normal weight (group I)	Overweight (group II)	Obese (group III)	
Patient number, n (%)	**124 (100%)**	**39 (31.5%)**	**41 (33.1%)**	**44 (35.4%)**	**p**
Sex					
Female, n (%)	60 (48.4%)	18 (30%)	20 (33.3%)	22 (36.7%)	0.939
Male, n (%)	64 (51.6%)	21 (32.8%)	21 (32.8%)	22 (34.4%)	
Age (years), median (min-max)	49 (22-69)	49 (28-66)	47 (22-69)	49 (25-68)	0.437
BMI (kg/m^2), mean ± SD	28.5±5	23.2±1.6	27.8±1.3	33.9±3.3	-
Stage 1 HT, n (%)	45 (36.3%)	13 (33.3%)	15 (36.6%)	17 (38.6%)	0.881
Baseline SBP (mmHg), mean ± SD	124.2±16.1	122.8±15.8	121.9±16.6	127.7±15.6	0.204
Baseline HR (BPM), mean ± SD	96.1	97.2	94.3	96.9	0.633
Target HR (%)	93.2±6.1	91.6±6.3	94±6.4	93.9±5.6	0.155
Exercise time (minutes), mean (min-max)	7.9 (6-11.4)	8.5 (6-11.4)	8.1 (6.1-10.5)	7.5 (6-10.1)	0.013
MET, mean (min-max)	9.38 (7-12.8)	9.69 (7-12.8)	9.71 (7.3-12.8)	8.8 (7-11)	0.010

BMI: Body mass index, HR: heart rate, HT: hypertension, MET: metabolic equivalent, SBP: systolic blood pressure, SD: standard deviation, BPM: beat per minute, min: minimum, max: maximum

(p=0.881). There was a significant difference between the three groups in terms of exercise duration (p=0.013), and it was found that normal weight patients exercised longer than obese patients in the paired comparison (p=0.017). Correspondingly, the metabolic equivalent (MET) value achieved was significantly different between the groups (p=0.010); particularly, it was lower in the obese group than the normal and overweight groups (p=0.030 and 0.024, respectively). In all three groups, a significant increase was seen in SBP and HR during exercise and a significant decrease in the recovery phase as expected. However, there was a statistical difference in terms of mean SBP and average ΔSBP among the three groups (p<0.05; Table 2). In cross-group comparisons of mean SBP, a significant difference was observed between the normal and obese groups in the 3rd minute (p=0.004; Table 3). Obese patients had greater SBP responses. In the 6th minute and at peak exercise, the difference was more apparent between the normal and obese groups in terms of mean SBP and ΔSBP (p<0.001). The overweight and obese groups had significantly higher mean SBP and ΔSBP values than the normal group at the 2nd minute of recovery phase (p=0.005 and <0.001, respectively). In short, the SBP of the obese and overweight groups remained higher in the early recovery phase.

When average ΔSBP values were compared, statistical difference was observed between the normal and overweight groups and between the normal and obese groups at the 3rd minute, peak level, and at the 2nd minute of recovery. As the exercise duration is prolonged, ΔSBP observed during the 6th minute and peak exercise increased significantly more in the overweight and obese groups than in the normal group (p<0.001) and remained more hypertensive at the early phase of recovery.

Comparison of the mean HR and ΔHR is summarized in Table 4. There was a statistical difference in HR at the 3rd and 6th minutes of exercise with respect to mean HR and mean ΔHR among groups. Analysis revealed that the obese group had significantly higher HR levels in the 3rd and 6th minutes of exercise than the normal group (p<0.001 and 0.003, respectively; Table 5). No differences were found among groups in terms of peak exercise and recovery phase HR values.

Discussion

Dynamic exercise increases HR and blood pressure due to sympathetic tonus activation to provide adequate oxygen to fulfill the metabolic demand of exercising muscles and to guarantee metabolic end-products washout (18). Similarly, in our study, SBP and HR increased parallel to exercise duration in all groups.

The purpose of the exercise testing is to evaluate cardiovascular responses to exercise. In addition to the standard effort capacity and ischemia assessment, this test is also important in terms of blood pressure response (19). There are studies on the usability of exercise testing including indirectly evaluating endothelial dysfunction in both normotensive and hypertensive patients and determining the relationship between blood pressure response to exercise and HT development in the future. A study by Tsumura et al. (20) revealed that

Table 2. Systolic blood pressure changes among groups during exercise test

	Normal weight (Group I)	Overweight (Group II)	Obese (Group III)	p
SBP (mmHg) 3rd minute	138.0±16	147.4±22.7	152.4±20	0.005
SBP (mmHg) 6th minute	148.4±18.2	160.5±21.1	174.3±20.8	<0.001
SBP (mmHg) peak	165.4±21.8	177.0±19.1	186.8±19.7	<0.001
SBP (mmHg) recovery 2nd minute	135.9±20.9	151.0±22	164.8±21	<0.001
ΔSBP (mmHg) 3rd minute-baseline	15.2±10.5	25.5±15.8	24.7±15.3	0.002
ΔSBP (mmHg) 6th minute-baseline	25.6±14	38.6±14.4	46.6±17.4	<0.001
ΔSBP (mmHg) peak-baseline	42.6±16.8	55.1±15.6	59.1±16.3	<0.001
ΔSBP (mmHg) recovery 2nd minute-baseline	13.1±14.8	29.1±15.2	37.1±16.6	<0.001

Data are presented as mean ± standard deviation.
SBP: Systolic blood pressure, Δ: changes in levels (mmHg)

Table 3. Comparison of the systolic blood pressure responses among groups (p-values)

	Normal vs overweight	Normal vs obese	Overweight vs obese
SBP (mmHg) 3rd minute	0.089	**0.004**	0.488
SBP (mmHg) 6th minute	**0.022**	**<0.001**	**0.005**
SBP (mmHg) peak	**0.031**	**<0.001**	0.071
SBP (mmHg) recovery 2nd minute	**0.005**	**<0.001**	**0.010**
ΔSBP (mmHg) 3rd minute-baseline	**0.004**	**0.008**	0.958
ΔSBP (mmHg) 6th minute-baseline	**0.001**	**<0.001**	**0.045**
ΔSBP (mmHg) peak-baseline	**0.002**	**<0.001**	0.499
ΔSBP (mmHg) recovery 2nd minute-baseline	**<0.001**	**<0.001**	0.052

Mean SBP values were analyzed between binary groups. A p-value of <0.05 was considered statistically significant.
SBP: Systolic blood pressure, Δ: changes in levels (mmHg)

an exaggerated increase in blood pressure during exercise is associated with an elevated risk of developing HT.

Not only the exaggerated SBP but also DBP response to exercise was reported as associated with an increased risk of developing future HT in the Framingham Heart study (21).

There are also studies with different results that examine the prognostic significance of the increase in blood pressure during exercise stress testing. Gupta et al. (22) reported that the increase in SBP >44 mmHg, especially during peak exercise, was associated with better survival rates both in normotensive and hypertensive subjects (22). However, Kurl et al. (23) evaluated the increase of >19.7 mmHg every 1 min of exercise and found that exaggerated blood pressure increase was related to stroke. Obesity is a risk for developing HT, and the increase in body composition is linked to SBP response to exercise (24).

In our study, the mean SBP and ΔSBP from the beginning of exercise was significantly higher in the obese and overweight groups than in the normal group. Similar to our study, there are studies in the literature showing that ΔSBP during exercise tends to increase with obesity, mainly due to autonomic dysfunction by using methods such as isometric exercise, dynamic exercise, and cold pressor tests (11,13,25,26).

In the assessment of the mean SBP and ΔSBP from baseline to the 2nd minute of recovery, we observed that overweight and obese patients' blood pressure at the end of recovery remained significantly higher than the normal group.

Data on the importance of SBP, not decreasing properly in the recovery phase, were highlighted in the Framingham Heart study. It has been reported that the resistant high SBP, which continues up to the 4th minute in the recovery phase after exercise, is significant in terms of developing HT in the future. In middle-aged men, blood pressure in the recovery phase of the exercise testing and the risk of acute myocardial infarction were investigated, and patients with >195 mmHg SBP response after exercise have 1.69 times higher risk of acute myocardial infarction than patients with <170 mmHg blood pressure response (27).

We also evaluated HR and found that the mean HR and ΔHR were higher in the 3rd and 6th minutes of the exercise in the obese group than in the normal group. Impaired HR recovery after exercise was observed three times more prevalent in obese patients and twice in overweight patients than in those with normal BMI in a study by Barbosa Lins et al. (28). It is also broadly identified in the literature as a powerful and independent cardiovascular predictor and all-cause mortality in healthy adults and cardiovascular disease and diabetes patients (28,29).

However, our study is incompatible with the literature, and the groups' blood pressure responses and peak exercise HR or recovery phase HR values were similar.

The explanation of these unexpected results are as follows: Even in young male obese healthy subjects, a significant negative correlation between BMI and VO2 max was observed by Laxmi et al. (30), reflecting relationship between overweight and poor cardiorespiratory fitness status. Similarly, in our study, exercise capacity, especially in the obese group, was lower than in the normal group, based on exercise duration and achieved MET levels. As we observed more in the obese patient group, when the age-adjusted target HR was reached, the test was terminated if the patient described fatigue. So, the overweight and obese groups might have achieved submaximal peak exercise and had lower peak HR increase than expected compared with the normal group that performed better and longer and so has reached the maximal HR value. Therefore, a difference in the peak HR and early recovery phase HR might not be observed.

Additionally, negative chronotropic drug use could affect peak HR responses to exercise testing. Although HT frequency was similar between the groups, we do not know whether negative chronotropic drug usage was different among patients.

Table 4. Comparison of the heart rate changes between groups

	Normal weight (group I)	Overweight (group II)	Obese (group III)	p
HR (BPM) 3rd minute	118.5±17.3	120.8±18.1	129.2±18.3	**0.018**
HR (BPM) 6th minute	134.3±17	137.4±17.3	143.8±17.7	**0.044**
HR (BPM) peak	157.5±11.3	160.8±15.1	159.3±13.6	0.567
HR (BPM) recovery 2nd minute	112.3±12.8	114.8±18.5	116.8±13.6	0.486
ΔHR (BPM) 3rd minute-baseline	21.4±11.8	26.5±12	32.3±12.8	**<0.001**
ΔHR 6th minute-baseline	37.1±14	43.1±13,3	46.9±12.7	**0.005**
ΔHR peak-baseline	60.4±16.8	66.5±18.4	62.3±14.8	0.247
ΔHR recovery 2nd minute-baseline	15.1±12.6	20.5±14.4	19.8±12.7	0.145

Data are presented as mean ± standard deviation.
HR: Heart rate, BPM: beat per minute, Δ: changes in level (mmHg)

Table 5. Double group comparison results of heart rate responses (p-values)

	Normal vs overweight	Normal vs obese	Overweight vs obese
ΔHR (BPM) 3rd minute-baseline	0.153	**<0.001**	0.080
ΔHR (BPM) 6th minute-baseline	0.114	**0.003**	0.393

HR: Heart rate, BPM: beat per minute, Δ: changes in level (mmHg)

Study Limitations

The limitations of our study are as follows: because of the retrospective nature, we did not have detailed information about the subjects' stage 1 anti-hypertensive treatments or basal exercise capacity, smoking history, or regular exercise status, which might have influenced our results. Diabetes is considered the equivalent of cardiovascular disease today, and it is closely related to obesity. Therefore, patients with diabetes were excluded to minimize the effects of microvascular and macrovascular complications of diabetes on the study results, but in our study, prediabetes status could not be ruled out with the available data.

Conclusion

We observed that, especially in obese patients with BMI >30, SBP increased to higher values during exercise and showed greater level changes from baseline compared with normal patients. During the recovery period, SBP values remained higher in overweight and obese patients. HR increase was apparent in the obese group during the early phase of exercise and was unexpectedly similar at the peak and recovery phases between groups. The office blood pressure measurements may not uncover masked HT, especially in overweight and obese individuals with an active lifestyle. Thus, exercise testing can help detect individuals in this population with exaggerated blood pressure response to exercise who are at risk of developing HT and cardiovascular disease in the future and to direct them to early exercise and weight loss programs.

Ethics Committee Approval: The study protocol has been approved by the University of Health Sciences Turkey, İstanbul Training and Research Hospital Local Hospital Ethics Committee (approval number: 237, date: 22.02.2013).

Informed Consent: Written informed consent was obtained from all patients.

Peer-review: Externally and internally peer-reviewed.

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