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ORIGINAL ARTICLE

Blood pressure in controlled hypertensive patients during exercise stress tests

Maria Viorela Dobroiu[1,2], Ion Relu Ondin Zaharia[1,2], Diana Cornelia Nistorescu[1,2], Camelia Nicolae[1,2], Ioan Tiberiu Nanea[1,2]

Abstract: Background – Ergometer bicycle and treadmill exercise tests are used for diagnosing ischemic heart disease. Measurement of blood pressure (BP) during exercise test is mandatory. Gender, weight, body mass index(BMI) influence BP response during exercise. But how are controlled hypertensive patients reacting to exercise testing? **Aim –** BP response assessment during exercise test in controlled hypertensive patients in relation to gender, weight, BMI. **Method –** 58 controlled (normal BP values in ambulatory blood pressure monitoring (ABPM) for minimum 2 weeks) hypertensive patients (54.78±11.41years) underwent treadmill or bicycle submaximal exercise test (target heart rate (220-age-years) x85%). They were assessed with ABPM and transthoracic echocardiography for left ventricular hypertrophy. **Results –** Mean maximal BP during submaximal bicycle exercise test is higher than mean maximal BP during submaximal treadmill exercise test (systolic BP 177,12mmHg vs. 160.63mmHg, p<0.05 and diastolic BP 92.24mmHg vs. 86.59mmHg, p <0.05). Weight and BMI can influence BP response in case of bicycle testing (R2= 0,16, β = 0,43, p < 0,005 respectively R2= 0,11, β = 0,33, p < 0,05). Men have higher systolic (t(15) = - 1.89, p < 0.05) and diastolic (t(56) = - 2.37, p < 0.05) BP than women during exercise stress test. **Conclusions –** Exercise BP response in controlled hypertensive patients is influenced by the type of exercise stress test, gender, weight and BMI simultaneously. Maximal BP values in relation to the submaximal effort test are higher for bicycle than treadmill. In the latter case the effort of peripheral muscle groups increases vasodilatation.
Keywords: arterial hypertension, exercise testing, treadmill, bicycle

Rezumat: Introducere – Bicicleta ergometrică și covorul rulant sunt folosite pentru diagnosticarea bolii cardiace ischemice. Măsurarea presiunii arteriale (TA) în timpul testării este obligatorie. Genul, greutatea, indexul de masă (IMC) influențează răspunsul TA la efort. Însă cum reacționează pacienții hipertensivi controlați la efort? **Obiectiv –** Evaluarea răspunsului TA la pacienții hipertensivi controlați la efort fizic în relație cu genul, greutatea, IMC. **Material și metodă –** 58 de pacienți (54,78±11,41 ani) hipertensivi controlați terapeutic (valori normale la monitorizarea ambulatorie a TA, cel puțin 2 săptămâni) au efectuat test de efort submaximal (frecvența țintă (220-vârsta-ani)x85%) pe bicicletă sau covor rulant. Au fost evaluați prin MATA și ecocardiografie transtoracică (evaluează hipertrofia ventriculului stâng). **Rezultate –** Valorile TA maximale la efort la pacienții supuși unui efort submaximal pe bicicletă au fost mai mari față de cei testați pe covor rulant (TA sistolică 177,12 mmHg vs. 160,63 mmHg, p<0,05 și TA diastolică 92,24 mmHg vs. 86,59 mmHg, p <0,05). Greutatea și IMC-ul influențează răspunsul TA pe bicicletă (R2= 0,16, β = 0,43, p < 0,005 respectiv R2= 0,11, β = 0,33, p < 0,05). Bărbații au Tasistolică (t(15) = - 1,89, p < 0,05) și diastolică (t(56) = - 2,37, p < 0,05) în timpul efortului submaximal mai mare față de femei. **Concluzii –** Comportamentul TA la efort la hipertensivii controlați terapeutic este influențat de tipul de testare la efort, de gen, de IMC simultan. Valorile TA maximale în raport cu testul de efort submaximal sunt mai mari pe bicicletă față de covor rulant, când efortul fizic al grupelor musculare periferice asociază vasodilatație arterială superioară.
Cuvinte cheie: hipertensiune arterială, testare la efort, bicicletă, covor rulant

[1] „Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania
[2] Departament of Internal Medicine and Cardiology, „Prof. Dr. Th. Burghele" Clinical Hospital, Bucharest, Romania

Contact address:
Maria Viorela Dobroiu, „Prof. Dr. Th. Burghele" Clinical Hospital, 20 Panduri Street, 5th District, Bucharest, Romania.
E-mail: deaconumv@gmail.com

INTRODUCTION

The benefit of exercise for the cardio-vascular system is well-known[1]. Guidelines highlight that physically active people have healthier body and mind[2]. Strong scientific evidence demonstrates that moderate exercise decreases the cardiovascular risk factors and overall mortality[3]. A lot of studies have documented that physical activity can modify the prognostic of some diseases such as ischemic heart disease, chronic kidney disease, type 2 diabetes mellitus, osteoporosis, depression and anxiety.

Hypertension is one of the most studied diseases in the late 20th century. Research progress regarding the risk factors and treatment is impressive[5]. About 9.4 million people suffer a cardiovascular event or die because of arterial hypertension. Experts approximate this number increasing to 1.5 billion in 2025[6,7]. Developed countries try to diminish hypertension risk by applying training programs. The goal is to present people the risks and treatments they could get. Everybody could get access to pharmacological or non-pharmacological treatments, to lessons about diet, physical exercise or about others changes of life style.

It is well known that exercise training helps decrease the value of blood pressure (BP). Most of the studies are about aerobic exercises because they need no special devices. How physical activity lowers systemic BP is not completely understood. A paper in 2016, explains some mechanisms of BP reduction during exercise[8]. There are four main factors that induce the rise of systemic BP: sympathetic innervation, arteriolar constriction, amplification of heart contraction and increased filling pressure. They all help in delivering oxygen and nutrients to active muscles[9]. Depending on the type of exercise some muscle groups are used more intensively. Exercise can be dynamic or static if classified by the mechanics, and aerobic or anaerobic if classified by metabolism[10].

Usually, in clinical practice exercise testing can be performed mainly with two devices: treadmill and bicycle. These two assume dynamic endurance effort with a smaller or bigger component of static effort[11].

SUBJECTS AND METHODS

This study was performed in the Internal Medicine and Cardiology unit at “Prof. Dr. Burghele” Hospital. 58 controlled hypertensive patients (Table 1) were recruited to perform exercise stress testing: 41 using the bicycle and 17 using the treadmill. All subjects were caucasian, 27 male and 31 female with ages between 21 and 74 years old.

They are hypertensive (stage one, two or three[11]) receiving pharmacological treatment: diuretics, calcium channel blockers, angiotensin receptor blockers, angiotensin converting enzyme inhibitors, beta blockers and centrally acting antihypertensive, in mono-therapy or in combination (Table 2). Anamnesis and clinical examination were performed for each patient.

Routine blood tests, 12 lead rest electrocardiogram and transthoracic echocardiography were performed. Individuals with heart failure, secondary hypertension, electrolytes abnormalities, severe kidney disease or any other serious disorder (pulmonary, digestive, haematologic) or with contraindication for exercise stress testing were excluded from this study.

After at least 2 weeks of treatment they were rechecked in a control visit. An ambulatory blood pressure monitor device (ABPM) was set up for 24 hours (General Electric Tonoport V Version). It was applied

Table 1. Demographic characteristics of the study group (N=58)

	Minimum	Maximum	Mean	Std. Deviation
Age	21	74	54.78	11.411
Weight (kg)	40	127	80.4	17.36
Height (m)	1.55	1.9	1.68	0.09
BMI (kg/m^2)	16.02	39.20	28.06	4.61
Weight-women (kg) (N=31)	40	95	69.9	12.7
BMI-women (kg/m2) (N=31)	16	36.7	26.3	4
Weight-men (kg) (N=27)	70	127	92	14.5
BMI-men (kg/m^2) (N=27)	24.2	39.2	29.9	3.8
LVPW (mm)	6	14.02	10.15	1.74
IVS (mm)	7	15.5	10.80	1.85
LV mass (g)	92	284	181.55	47.78
LV index mass (g/m^2)	54	155	93	19.65
LVEF (%)	50	77.4	60.33	4.94

LVPW = left ventricular posterior wall; IVS = inter ventricular septum; LV = left ventricular; LV Index mass = left ventricular index mass; LVEF = left ventricle ejection fraction.

Table 2. Characteristics of the study group (frequency and percent)

	Frequency	Percent%
Female	31	53.4
Male	27	46.6
Diabetes mellitus	10	17.2
Underweight	1	1.7
Normal weight	11	19
Overweight	27	46.6
Class I obesity	13	22.4
Class II obesity	6	10.3
Stage I hypertension	5	8.6
Stage II hypertension	30	51.7
Stage III hypertension	23	39.7
Beta blockers	28	48.3
Diuretics	43	74.1
ARBs	11	19.0
Calcium channel blockers	21	36.2
ACEI	43	74.1
Others drugs	6	10.3
Compliance	51	87.9

ARBs = angiotensin receptor blockers; ACEI = angiotensin converting enzyme inhibitor.

to the non-dominant arm using corresponding cuff. They received ABPM from the beginning if they already had been diagnosed and treated for systemic hypertension. The recordings were processed in order to determine if the patient is controlled.

If the patient is controlled, he/she performed stress testing using treadmill Schiller Inter Track 8100 TMed type or ergometer bicycle Ram 660 BP, version in 7 steps. Laboratory and equipment where assessed for the standard request[10]. BP was automatically measured every 2 minutes during the test using the same device. The target heart rate was calculated by the formula (220-age (years)) x 85% for both devices. All patients achieved submaximal effort level 10. The bicycle test started with 25W for 1 minute and the workload was increased by 50W every 3 minutes. The treadmill was conducted in stages of 3 minutes each, starting with a low speed and ramp, and increasing progressively (Bruce protocol for treadmill). The exercise test was stopped if the target heart rate was reached, if systolic BP was >220 mmHg, if diastolic BP was >110 mmHg 10 or if any of the guideline indications of stopping occurred during the test[10]. If patients did not reach target heart rate or the test was positive they were excluded from the study. After the test was stopped the subjects continued to walk or pedal for 7 minutes at a low speed until the recovery stage is complete.

DATA ANALYSIS

Data was analyzed using SPSS. Categorical variables were expressed as proportions and percentages and continuous variables were expressed as means ± standard deviation. Student T-test was used to compare maximal systolic and diastolic blood pressure during exercise on treadmill or on bike. For categorical variable Chi-square test was used. $P<0.05$ was consider statistically significant.

RESULTS

Descriptive characteristics were established for the two groups and for all subjects. 58 controlled hypertensive patients were recruited to perform exercise stress testing. 41 subjects used the ergometer bicycle and 17 used the treadmill. There were 27 male and 31 female with age between 21 and 74 years old (mean age 54.5 years). Females had average weight 69.9 kg (minimal 40kg and maximal 95kg standard deviation 12.7kg) with average body mass index (BMI) 26.3kg/m^2 (range 16kg/m^2 and 36.7kg/m^2, standard deviation 4 kg/m^2) and males had average weight 92 kg (minimal 70 kg and maximal 127 kg, standard deviation 14.5 kg/m^2) and BMI 29.9 kg/m^2 (range 24.2 kg/m^2 and 39.2 kg/m^2, standard deviation 3.8 kg/m^2). Most of them (27 patients) were overweight (Table 2).

5 subjects had first stage hypertension, 30 subjects had second stage hypertension and 23 third stage hypertension according to the 2013 European Guidelines for the management and treatment of arterial hypertension[11]. All patients received medications, monotherapy or combination of antihypertensive drugs. Most of them received diuretics and angiotensin converting enzyme inhibitors (43 from total of 58), 28 received beta blockers, 11 angiotensin receptor blockers, 21-calcium channel blockers (amlodipine) and 6 centrally acting antihypertensive. Table 3 presents the incidence of left ventricle concentric remodeling or hypertrophy.

There was no significant difference between the two groups (bike or treadmill) or between men and women. Also there was no statistically significant difference regarding the treatment profile. Mean maximal systolic BP on ergometer bicycle was significantly higher than mean maximal systolic BP on treadmill (177.12 vs. 160.63, $p=0.011$). Mean diastolic maximal BP was significantly higher in the ergometer bicycle group (92.24 vs. 86.59, $p=0.016$) Table 4, Figure 1.

Linear regression was used to determine if weight is an independent factor and predictor for exercise

Table 3. Incidence of left ventricle remodeling, concentric or eccentric hypertrophy

		Frequency	Percent	Valid Percent	Cumulative Percent
	Normal	25	43.1	43.1	43.1
	concentric remodeling	18	31.0	31.0	74.1
	concentric hypertrophy	13	22.4	22.4	96.6
	eccentric hypertrophy	2	3.4	3.4	100.0
	Total	58	100.0	100.0	

Table 4. Comparison of maximal exercise blood pressure in ergometer bicycle and treadmill groups

	Effort type	N	Mean	Std. Deviation	Std. Error Mean
sBPmax	Bike	41	**177.12**	24.052	3.756
	treadmill	17	160.59	14.239	3.454
dBPmax	Bike	41	**92.24**	9.962	1.556
	treadmill	17	85.59	7.263	1.762

	t-test for Equality of Means				
	t	df	Sig. (2-tailed	Mean Differeance	Std. Error Difference
sBPmax	2.641	56	**.011**	16.534	6.261
dBPmax	2.489	56	**.016**	6.656	2.674

sBPmax = maximal systolic blood pressure; dBPmax = maximal diastolic blood pressure.

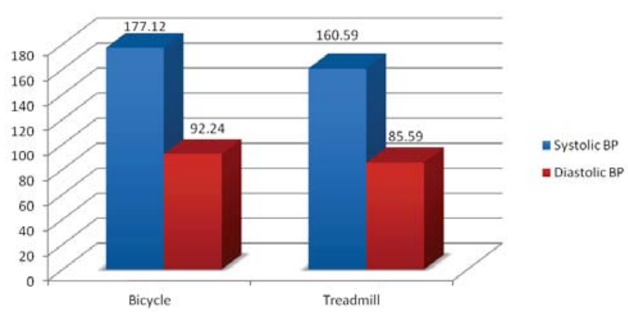

Figure 1. Comparison of maximal exercise blood pressure in ergometer bicycle versus treadmill patients groups, in relation with submaximal stress test (see text).

blood pressure. Results show that the weight (R2= 0.16, β = 0,43, p < 0,005) and BMI (R2= 0.11, β = 0,33, p < 0,05) are significantly independent factors and predictors for systolic BP from bicycle exercise testing (Table No 5) (Figure No 2 and 3), but not for systolic BP on treadmill (Weight: R2= 0.11, β = 0.40, p > 0.10, BMI: R2= - 0,03, β = 0.18, p > 0.48) (Figure 4 and 5).

No significant difference regarding the antihypertensive medication among the two groups (bike or treadmill exercise) was seen. Left ventricle mass, left ventricle mass index, hypertrophy type or left ventricle ejection fraction did not influence the BP response during the two exercise testing.

Males had higher systolic and diastolic BP values than female during exercise testing regardless of the device used. The same result was found for bicycle testing (males had higher systolic and diastolic BP). For the treadmill group results were marginally significant (maybe due to the small number of participants).

Patients with first stage hypertension had lower diastolic BP during exercise than patients with second and third stage hypertension.

DISCUSSION

Cardiovascular response to exercise was studied extensively. Literature suggests that resting arterial blood pressure has a strong influence on exercise BP.

Table 5. Weight and BMI are independent predictors for systolic BP on bicycle exercise

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	131.967	15.310		8.619	.000
	G (kg)	.554	.183	.436	3.026	.004
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
1	(Constant)	130.675	20.928		6.244	.000
	BMI (kg/m^2)	1.668	.740	.339	2.253	.030

G = weight; BMI = body mass index.

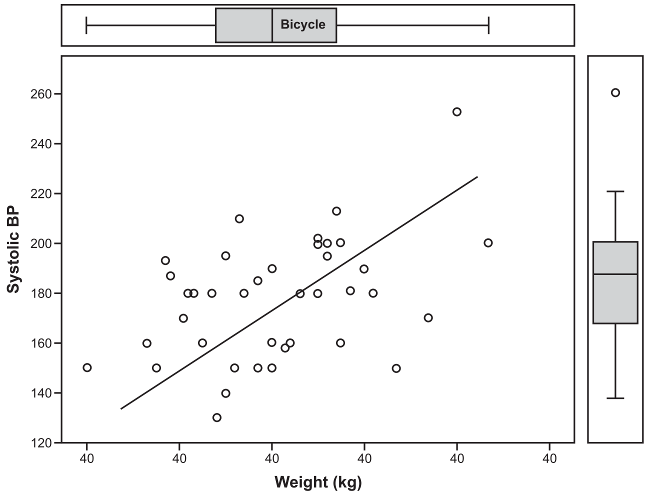

Figure 2. Weight is an independent factor and predictor for systolic BP for bicycle exercise testing.

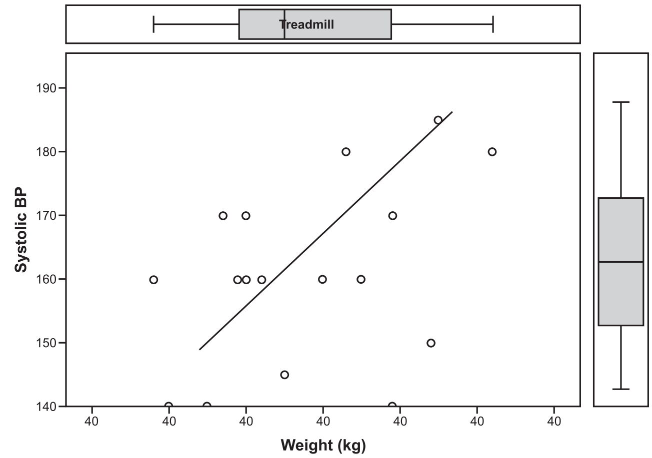

Figure 4. Weight is not an independent factor and predictor for systolic BP for treadmill exercise testing.

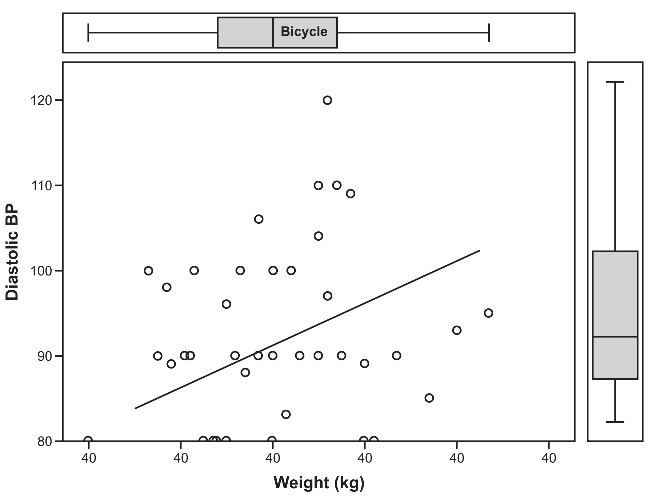

Figure 3. Weight is an independent factor and predictor for diastolic BP for bicycle exercise testing.

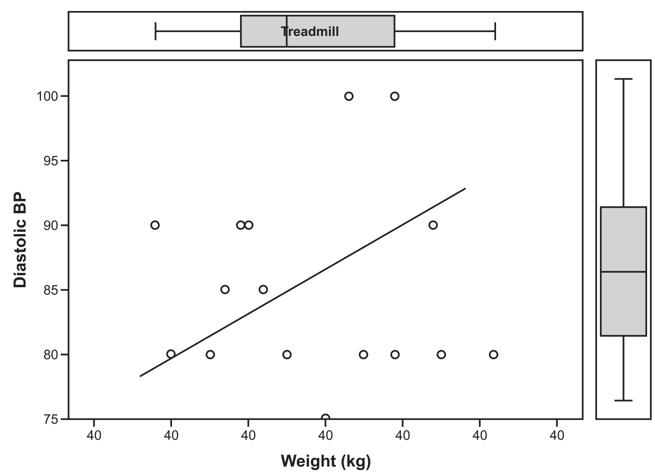

Figure 5. Weight is not an independent factor and predictor for diastolic BP for treadmill exercise testing.

It seems that age and BMI are not very important in exercise response[12].

These study results show that the patients with first stage hypertension had lower diastolic BP during exercise than patients with second and third stage hypertension and men had higher systolic and diastolic BP during exercise stress tests than women.

The impact of exercise type (isometric or isotonic) on the cardiovascular system, especially BP was less studied. Exaggerated blood pressure response in normotensive patients is considered systolic blood pressure ≥210mmHg for men and ≥190mmHg for women and diastolic blood pressure ≥90mmHg for both genders10. But the same guidelines propose relative indication for stopping the exercise testing if systolic BP is above 250mmHg or diastolic BP above 115mmHg[11]. Many physicians do not agree with these values. They consider them exaggerated with risk for cardiovascular events. This risk would increase in hypertensive patients with subclinical organ damage. Guidelines mention that there is insufficient data to support this issue[10].

All these cut off values are for normal BP values at rest. Can these values be used for hypertensive subjects who are receiving treatment and have normal ABPM values? This study tries to achieve more data about BP response to exercise in controlled hypertensive subjects. It suggests that the type of exercise stress test has a role in BP response. Systolic and diastolic BP is higher for the group who used the ergometer bicycle. Active muscle involved in walking and running on treadmill are higher than in cycling. Cyclists mostly use the quadriceps muscle (a big active muscle). Subjects from treadmill group use more muscles so they produce more vasodilation than the bike group. This could explain the results of this study. Another explanation could be that it is easier to measure BP on a bike. Thus the accuracy is lower for the treadmill group because of constant motion.

This study found that weight and BMI are significantly independent factors and predictors for systolic BP for bicycle exercise testing, but not for systolic BP of those tested on treadmill. Contrary, some studies show that weight is important in exercise testing on treadmill[13].

In several trials the treadmill appears to be less applicable than bicycle in exercise testing. Cycle allows more accuracy and stability for electrocardiography recording and BP measurement[14].

LIMITATIONS OF THE STUDY

One limitation is the small number of subjects. Even if the BP was determined automatically there may by differences of systolic and diastolic values during exercise stress tests methods (bicycle or treadmill).

CONCLUSION AND FUTURE PERSPECTIVES

Exercise stress test on bicycle respectively treadmill influence the BP response in different ways. Thereby maximal BP is higher during bicycle versus treadmill exercise test. The results of this study can change recommendations for non-pharmacological treatment for hypertension. New maximal cut-off BP values should be established for hypertensive patients during different methods of exercise tests in clinical departments. Especially these new maximal cut-off BP values should be used for hypertensive patients who are controlled by medication.

Further research is required for a better understanding of exercise BP response during different stress tests in normal and hypertensive subjects.

Conflict of interest: none declared.

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