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The determinants of blood pressure response to exercise

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ABSTRACT

Introduction: There is currently no consensus on the definition of normal BP (blood pressure) increase during exercise and thus of the exaggerated BP response to exercise. The aim of the present study was a description of the relationship between BP and work rate corrected by body weight on cycle ergometer. A secondary objective was to explore the possible components of this relationship.

Materials and methods: An observational study with retrospective analysis of the BP data acquired during standard stress tests on cycle ergometer was performed. For the analysis each work rate was expressed corrected to the patients' body weight.

Results: We analysed BP data from a total of 313 stress tests. From the linear regression analysis we found that at the first exercise step systolic BP depends primarily on resting BP ($p = 0.001$), on W/kg ($p = 0.001$), on BMI ($p = 0.005$) and age ($p = 0.002$) ($BP = -25.059 + 0.927*BP_{rest} + 31.625*W/kg_1 + 0.840*BMI + 0.235*age$) and diastolic BP depends primarily on resting BP ($p = 0.001$), and on resting diastolic BP ($p = 0.033$): $BP = 29.790 + 0.583*BP_{rest} + 0.071*BP_{rest}$. On subsequent steps age did no more influence systolic BP and resting diastolic BP remained the main determinant of diastolic BP.

Conclusion: The main finding of this study is the confirmation that the exercise blood pressure depends principally on resting blood pressure and work rate and to a lesser amount on BMI and age. In future studies work rate should be corrected by body weight at submaximal levels.

Introduction

Elevated resting blood pressure (BP) is an established predictor of cardiovascular morbidity and mortality and it is one of the components of total cardiovascular risk in SCORE charts [1]. BP increases physiologically during exercise to enable adequate blood supply to working muscles [2] and its increase is proportional to exercise intensity [3]. There is currently no consensus on the definition of normal BP increase during

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exercise and thus of the exaggerated blood pressure response to exercise (ExBP) [4].

Several studies have used ExBP to predict the development of future hypertension [5–7] and cardiovascular events [8–10]. These studies were conducted principally on treadmill and used mostly peak systolic BP or absolute increase from resting to peak values of the systolic BP [11].

The expression of the work intensity corrected to body weight on the cycle ergometer is linearly proportional to the multiples of the metabolic equivalents (METs). Only minority of the studies used METs for the correction of blood pressure response to exercise and all except one were performed on treadmill [5,6,12,13]. We found no studies on cycle ergometers taking into account the weight of the patients for the correction of work intensity (in contrast on treadmill which is inherently a weight bearing exercise). Radvanský et al. used the definition of abnormal blood pressure response to exercise as any increase of more than 30 mmHg per 1.0 W/kg [14].

The aim of the present study was a description of the relationship between BP and work rate corrected by body weight on cycle ergometer. A secondary objective was to explore the possible components of this relationship.

Materials and methods

An observational study with retrospective analysis of the blood pressure data acquired during standard stress tests on cycle ergometer was performed. Basic demographic data and the patients' medication were recorded before each test. Data from a total of 313 stress tests performed between January 2011 and December 2012 were included. There were 136 patients with hypertension, who were taking a mean of 1.8 ± 0.9 antihypertensive drugs from all groups of antihypertensive drugs. Forty-three patients had known coronary artery disease; there were 37 patients with type 2 diabetes, and 17 patients had chronic obstructive pulmonary disease. One-hundred and sixty-four patients were taking drugs affecting blood pressure; 75 patients were taking beta-blockers and 7 patients were taking verapamil. Basic demographic data according to the presence or absence of clinically documented hypertension are summarised in Table 1. Suspected coronary artery disease was the clinical indication for the stress test in 184 patients, preventive check-out in 89 patients, dyspnoea in 27 patients, examination before non-cardiac surgery in 7 patients and blood pressure reaction to exercise in 6 patients.

Exercise stress tests on cycle ergometer (Ergoline e-bike, GE) were performed according to the guidelines of the Czech Society of Cardiology [15]. In brief, a 3-min work rate step protocol was used and the workloads were chosen by the attending physician in multiples of 25 W according to patients' age, performance status and comorbidities. On each step heart rate, systolic (BP_{sys}) and diastolic (BP_{dia}) blood pressures were recorded. The numbered suffixes correspond to the number of work rate step, and the suffix 0 is for baseline data.

For the analysis each workload was expressed corrected to the patients' body weight, i.e. workload divided by the body weight (W/kg) for each 3-min step.

Table 1 – Patients' demographic data according to the hypertensive status.

	Without hypertension	With hypertension
N	174	136
Age (years)	52 ± 13	59 ± 13*
Height (m)	174 ± 9	173 ± 9
Weight (kg)	81.2 ± 14.7	86.7 ± 17.4*
BMI (kg/m^2)	26.9 ± 4.0	28.9 ± 4.5*
N (without any medication)	91 (53%)	14 (10%)
N (with antihypertensive medication)	36 (21%)	116 (85%)
Number of antihypertensive drugs (mean ± SD)	1.7 ± 0.8	1.8 ± 0.9

* For $p < 0.05$.

Blood pressure measurements were done by one experienced nurse at the beginning of the third minute of each workload. Blood pressure was measured manually by an aneroid sphygmomanometer using the auscultatory method. BP_{sys} was recorded at the appearance of the Korotkoff phase I sound and BP_{dia} at the disappearance or muffling of the Korotkoff sounds (phase IV or V); the preference was at the complete disappearance of the Korotkoff sound, and in the case of uncertainty diastolic pressure was not noted. Heart rate was measured online from the ECG recording by the cardiological software (GE Cardiosoft V6.51).

For the purpose of the current study we included only exercise tests where the blood pressure was measured by the same experienced nurse. Exaggerated blood pressure response to exercise was considered if any measurement of blood pressure during the exercise test was higher than 200 mmHg for BP_{sys} or higher than 100 mmHg for BP_{dia}, for both male and female subjects [15].

Statistics

Data are expressed as mean ± standard deviation for numerical variables.

Between group differences were tested using Student's unpaired *t*-test.

Before linear regression analysis we calculated Pearsons' correlation coefficients separately for BP_{sys} and BP_{dia}. A linear regression analysis with multivariate models was used with stepwise variable selection.

The value of $p < 0.05$ was considered significant. All calculations were performed using statistical software SPSS 13.0 (SPSS Inc., Chicago, IL 60606-6412).

Results

From the 313 stress tests seven patients did not finish the entire first step; another 88 patients finished the exercise during the second step, and only 13 patients attempted the fourth step. The reasons for stopping the test were electrocardiographic changes ($n = 36$), blood pressure increase ($n = 7$) and the will of the patients to stop the test ($n = 17$), all other patients attained at least 85% of predicted hear rate.