The Value of Exercise Systolic Blood Pressure as an Indicator for Coronary Artery Disease in Normotensive Men

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Abstract

Aim: We investigated if rates of systolic blood pressure to workloads during exercise can independently predict coronary artery disease. **Methods**: 78 normotensive men with normal blood pressure who had exercise ECG stress test and a coronary angiography within 30 days were enrolled in the study. Basic features of all the patients were also compared. The rates of systolic blood pressure to workloads at the first stage, peak exercise, second, fourth and sixth minute of recovery were compared in normotensive men with both normal and abnormal coronary arteries. **Statistical analysis:** t test and stepwise regression was used. **Results:** The rates of systolic blood pressure to workloads were statistically importantly higher in men with normal blood pressure which had coronary artery disease compared to those with normal coronary arteries and normal blood pressure. **Conclusions:** In men with normal blood pressure high levels of systolic blood pressure to workload rates at the first stage to the end of exercise test can independently predict the presence of coronary artery disease, even in non-conclusive stress tests or when ECG doesn't show any change during exercise.

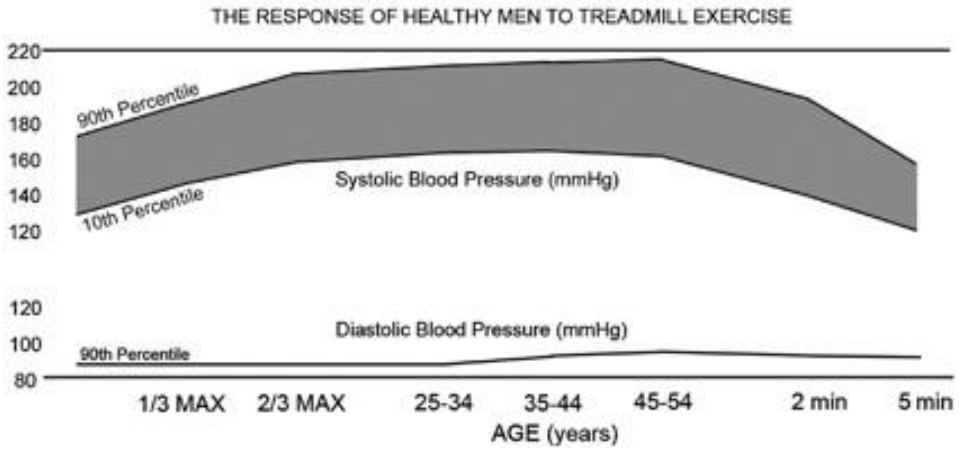
Keywords: Exercise, Systolic Blood Pressure, Coronary Artery Disease, Normotensive Men

Introduction

The cardiovascular response of the coronary artery disease patients differs from that of healthy people, independently of their physical training. This difference is present not only in peak exercise, but also in the initial and other stages of the stress test, and at the same time in the pattern of recovery after finishing the exercise. Thus, for a whole evaluation of the patient, concentrating only on the ECG changes in not sufficient. As a result, it is indispensable to observe the patterns of cardiovascular

response between patients and healthy people, and also between patients in good and weak physical shape.

Normal ranges of blood pressure are shown in Figure 1, which shows the changes in blood pressure response to treadmill exercise test in healthy men.



One of the most important cardiovascular response to exercise is the elevation of blood pressure. What matters is not only the inotropic competence of the heart, but also the inotropic reserve of the heart. In general, in patients with coronary disease the inotropic competence is low. In men with positive stress test in the first stage, both systolic blood pressure is higher and the inotropic reserve is higher than in patients with negative stress test. At the same time, often stress tests can be non-conclusive or the ECG during stress test doesn't change, and the physician needs more parameters to judge if the patient needs to be sent to coronary angiography. Chest pain during stress, arrhythmias or conduction abnormalities can be an indication for further evaluation. The pattern of blood pressure changing in the beginning, at every stage, at the peak and during the whole recovery of the exercise stress test can be very useful to discriminate the coronary artery disease patients from healthy ones. This study shows important evidence to this practice.

Nowadays, as a truth criterion of the positive result of the exercise stress test is a positive coronary angiography for significant atherosclerotic lesions. Coronary angiography defines not only the presence or not of coronary artery stenosis, but also their location and their severity. It also is crucial for determining the way the patient must be treated, including medical treatment or revascularization through percutaneous coronary intervention or coronary artery bypass grafting. But coronary angiography is an invasive procedure, with some risks and potential complications, and relatively costly. Also, as any other examination, it carries the risks of imperfect technicalities and subjective interpretation, so it cannot be an absolute true verifying criterion of the positive result of the exercise stress test. Furthermore, stress test is a functional test concerning the heart under stress conditions, while coronary

angiography is an anatomical method of observation in rest, needing physiological support, for example with intracoronary adenosine injection to show if the lesions are really ischemic or not.

From many studies it is documented that the results of the stress test is dependent on the prevalence of the coronary artery disease in the given population. The prevalence in itself is dependent on gender, age and risk factors for coronary artery disease.

Many studies have demonstrated an exaggerated systolic blood pressure (SBP) response in patients with coronary artery disease (CAD) by relating the recovery SBP to the Peak exercise SBP. While, their peak workload output is significantly diverse.

In the current study we have investigated the relative response of systolic blood pressure to workload (WL) during exercise but also

Methods

77 men with normal blood pressure aged 35 to 65 years old were included in this study. All of them had a symptom limited 3-minute stage progressive exercise test (ET) and their blood pressure measured at rest, at 3rd minute of each exercise stage, and at the 2nd, 4th and 6th minute of recovery. Stress tests were done with a bicycle ergometry. All patients underwent also a coronary angiography. In 43 of the patients stress test resulted positive for myocardial ischemia, in 22 patients stress test was negative and in other 12 patients was non-conclusive. Stress test is considered non conclusive when less than 85 % of maximal targeted heart rate achieved when their ECG doesn't fulfill criteria for positivity. According to the coronary angiography result patients were divided in two groups: the first group 34 individuals with normal coronary angiography (G1) and the second group 44 individuals with abnormal coronary angiography (G2). Ratios of SBP at starting step to starting workload and SBP at peak exercise, recovery minute 2, 4, and 6 with Peak workload were analyzed in both normotensive men with normal and abnormal coronary angiography.

Statistical analysis*:* Unpaired *t* test, simple and stepwise regressions statistical analysis of variables were used

Results

Baseline features of normotensive males with normal or abnormal coronary angiography like height, body mass index, left ventricle ejection fraction and blood pressure in rest and exercise were not statistically significant. Meanwhile age was statistically significantly higher in males with abnormal coronary angiography 53 vs 44 years old p 0.0004 starting and peak workload were statistically higher in males with normal coronary arteries respectively 39.09 vs 31.4 watts p 0.0004 and 144.8 vs 108.3 watts $p<0.0001$. Percentage target heart rate achieved was significantly higher in normotensive males with normal coronary arteries. (Table 1)

Characteristics	**Normal coron. Angiog Mean (SD)**	**P-Value**	**Abnorm coronary Angiog. Mean (SD**
Age, y	44 (9.8)	**0.0004**	53 (9.7)
Weight, kg	75 (13)	0.46	73.3 (8.4)
Height, m	1.70 (0.47)	0.6	1.70 (0.5)
Body mass index	25.8 (4.07)	0.4	25.2(2.5)
Ejection fraction, %	0.69 (0.09)	0.06	0.64 (0.13)
Systolic BP at rest, mm Hg	123 (9.1)	0.97	123 (8.8)
Systolic BP at the end of 1st exercise stage, mm Hg	139.6 (16.2)	0.73	141 (19.8)
Peak Systolic BP, mm Hg	183.3 (27.8)	0.14	173.5 (29)
Systolic BP at recovery 2nd min.	146.5 (18.6)	0.94	146.3 (19.41)
Systolic BP at recovery 4th minute	132.7 (16.1)	0.34	136 (15.83)
Systolic SB at recovery 6th minute	124.5 (10.8)	0.19	128.7 (15.02)
Starting work load, watt	39.09 (10.1)	**0.0004**	31.4 (8.2)
Peak work load, watt	144.8 (38.8)	**<0.0001**	108.3 (35.7)
Percentage target heart rate achieved	86.2 (11.4)	**<0.0001**	70.8 (11.3)

Table 1. Baseline characteristics of both normotensive men with normal and abnormal coronary angiography

All ratios of systolic blood pressure to workloads (WL) were statistically significantly higher in normal tension males with coronary artery disease. Table 2. For example the difference of the mean starting SBP / WL at first stage was 0.99 p 0.0009. The difference of the mean peak SBP / WL was 0.446 p 0.0007. The difference of the mean recovery second minute SBP / WL was 0.447 p 0.0002. The difference of the mean recovery fourth minute SBP / WL was 0.441 p 0.0001. The difference of the mean recovery sixth minute SBP / WL was 0.393 p 0.0003. (Table 2)

Table 2. Systolic blood pressure indices in both men with normal and abnormal coronary angiography

Systolic blood pressure index (SBPR)	Normal coronary angiography Mean (SD)	P-Value	Abnormal coronary angiography Mean (SD)
Starting SBPI	3.783 (1.06)	0.0009	4.773 (1.362)

Peak SBPI	1.344 (0.324)	0.0007	1.79 (0.609)
Recovery min.2 SBPI	1.083 (0.305)	0.0002	1.53 (0.576)
Recovery min.4 SBPI	0.979 (0.277)	<0.0001	1.42 (0.541)
Recovery min.6 SBPI	0.928 (0.262)	0.0003	1.321 (0.528)

Analyses of SBP/WL for sensitivity and specificity and test accuracy of the test in the first stage for the cutoff > 4.12 were respectively 70.5 %, 54.5 %, and 63.6 %. For the peak exercise for the cutoff > 1.425 were respectively 67.6 %, 62.1 % and 56.6 %. For the second minute of recovery for the cutoff > 1.323 were respectively 78 %, 55 % and 65.3 %. For the fourth minute of recovery for the cutoff > 1.117 were respectively 62.5 %, 67.7 % and 64.8 %. For the sixth minute of recovery for the cutoff > 1.08 were respectively 57.9 %, 67.7 % and 62.3 %. (Table 3) On the other hand ECG positive criteria of the stress test was respectively 91.7%, 65, 5% and 62.7%. in this test high SBP workload ratio can detect coronary artery disease despite ECG during exercise in males with normal blood pressure. Step wise regression showed that other parameters like height, body mass index, diastolic pressure doesn't have any influence.

	Cutoff	Sensitivity %	Specificity %	Test accuracy %
Start. SBPR	4.12	70.5	54.5	63.6
Peak SBPR	1.425	67.6	62.1	56.6
Recovery minute 2nd SBPR	1.323	78	55	65.3
Recovery minute 4th SBPR	1.117	62.5	67.7	64.8
Recovery minute 6th SBPR	1.08	57.9	67.7	62.3
ECG		91.7 (75)*	65.5 (55.9)*	66.7

Table 3. Sensitivity and specificity of SBPR-s in indicating CAD

Discussion

In normal individuals systolic blood pressure response is directly connected to the increase of the workload (WL). But this is partially true when there is CAD. There is no consensus which are the values of peak SBP that can be considered exaggerated blood pressure response. Investigators have considered as such the increase of peak SBP over 220 mmHg for males and 190 mmHg for females. Exaggerated increase of SBP during exercise is related mostly with the prediction of having high blood pressure in the future and only weakly with the presence of CAD or mortality. According to the fact that increasing blood pressure response is stimulated by the workload we have supposed that also the decrease of blood pressure during recovery is connected directly to workload and nor to peak SBP. As a consequence this could be shown by the rate of SBP to workload. Our results show that peak workload was significantly different being significantly lower with those with the presence of CAD Tab 1. It is evident that the increase of SBP in males with normal blood pressure and CAD is disproportionate to the increase of the workload. This disproportionate

increase of SBP to workload was evident in first stage SBP/WL ratios and in the peak SBP/WL ratios (tab. 2). So the increase of SBP should be considered exaggerated not based on the measured SBP values but from the value of SBP to workload rate (SBPR). This study documents that higher levels to SBP to workload rates can detect the presence of CAD in normotensive men with at least the same accuracy as ECG changes during stress test.

In special occasions the first stage SBP to WL rate can be of special importance because there are people that cannot perform more than one stage. In most of these cases stress ECG is normal and this SBP/WL rate in first stage is the only parameter that allows us to show the presence of CAD. Also our study shows that the slow SBP decrease during recovery can show the presence of CAD. But the rates of SBP to workload are more certain even if the peak SBP cannot be measured correctly. On the other hand the rates of SBP to WL represent sensitivity, specificity and test accuracy were totally comparable with ECG depression of ST segment during stress test. Stepwise regression analyze show that for the exercise SBP to workload rates only the starting workload and starting SBP and peak workload and peak SBP were determining factors meanwhile for the SBP to workload rates in recovery the only determining factor was the peak workload. This is a strong prove of our hypothesis that in normal people not only the increase of SBP during exercise but also the decrease of SBP during recovery are dependent on the workload. It is very important to emphasize that in normotensive males with or without CAD the rates of SBP to workload are not influenced by body mass index, systolic and diastolic blood pressure in rest.

Conclusion

In men with normal blood pressure high levels of ratios between systolic blood pressure to workload from the first stage to the end of exercise test can independently predict the presence of coronary artery disease, even in non conclusive stress tests or when ECG doesn't show any change during exercise.

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