Original Article

# Baseline Systolic Blood Pressure Response to Exercise Stress Test Can Predict Exercise Indices following Cardiac Rehabilitation Program

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## Abstract

**Background:** *Systolic blood pressure recovery (rSBP) is of prognostic value for predicting the survival and co-morbidity rate in patients with coronary artery disease (CAD). This study investigated the association between rSBP and exercise indices after complete cardiac rehabilitation program (CR) in a population-based sample of patients undergoing coronary artery bypass grafting (CABG).*

**Methods:** *The sample population consisted of 352 patients who underwent pure CABG. The patients underwent standard symptom-limited exercise testing immediately before and also after the completion of the CR sessions. rSBP was defined as the ratio of the systolic blood pressure at 3 minutes in recovery to the systolic blood pressure at peak exercise.*

**Results:** *An abnormal baseline rSBP after exercise was a strong predictor of exercise parameters in the last session, including metabolic equivalents ($\beta = -0.617$, $SE = 0.127$, p value $< 0.001$) and peak $O_2$ consumption ($\beta = -1.950$, $SE = 0.363$, p value $< 0.001$) measured in the last session adjusted for baseline exercise characteristics, demographics, function class, and left ventricular ejection fraction.*

**Conclusion:** *The current study strongly emphasizes the predictive role of baseline rSBP after exercise in evaluating exercise parameters following CR. This baseline index can predict abnormal METs value, peak $O_2$ consumption, post-exercise heart rate, and heart rate recovery after a 24-session CR program.*

*J Teh Univ Heart Ctr 4 (2010) 184-187*

**Keywords:** *Blood pressure • Rehabilitation • Coronary artery disease • Coronary artery bypass*

## Introduction

Exercise-induced changes of cardiovascular parameters are commonly used for the detection of coronary artery disease (CAD) as well as stratification of its risk and severity.[1] One of these changes that can be an important sign for detecting CAD severity and its related adverse events is a decrease in systolic blood pressure and systolic blood pressure recovery (rSBP), which is even more sensitive and specific than exercise-induced angina or ST segment depression.[2, 3]

Some previous studies have confirmed the high sensitivity, specificity, and accuracy of exercise-induced hypotension in comparison with ST-segment depression on the treadmill exercise testing for evaluating CAD and its severity.[4] In a study by Amon et al., rSBP was more sensitive than exercise electrocardiographic changes and angina for identifying patients with CAD.[5] Some other researches have shown a strong association between the angiographic severity of CAD and an attenuated rSBP.[6, 7] Furthermore, it has been hypothesized that rSBP immediately after exercise is of

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prognostic value in that it can effectively predict the survival and also co-morbidity rates in those with atherosclerotic heart disease.[8] It should be noted, however, that some other studies have not demonstrated this relationship.[9]

Despite the reported association between baseline cardiovascular indices and outcome of cardiac rehabilitation (CR), there have been no reports to date concerning the usefulness of baseline rSBP for predicting the outcome of a CR program in patients undergoing coronary interventions. This study was conducted to study the association between rSBP and outcome of a complete CR program in a population-based sample of patients undergoing coronary artery bypass grafting (CABG).

## Methods

The sample population consisted of CAD patients who underwent pure CABG and were referred to the CR Clinic at Tehran Heart Center between August 2008 and February 2009. Patients with a history of valvular or congenital heart disease, recent myocardial infarction, left ventricular hypertrophy, emphysema, end-stage renal disease, congestive heart failure, left bundle branch block, and atrial fibrillation as well as those with orthostatic hypotension or hypertension and those treated with digitalis, f3-blocking agents, calcium antagonist, and antiarrhythmic drugs were excluded. All the patients gave informed consent on the day of admission to rehabilitation, and the Review Board of Tehran University of Medical Sciences approved the study protocol.

Before exercise treadmill testing, the patients underwent structured interviews and chart reviews, yielding data on baseline characteristics, oral medication, coronary risk factors, prior cardiac events, and procedures. In addition, other medical diagnoses were performed. The obtained data were entered prospectively into an online structured computerized database.

The patients underwent standard symptom-limited exercise testing according to the Bruce protocol, modified Bruce, or Cornell protocol immediately before and also after the completion of the CR sessions. During each stage of exercise and during the first 3 minutes of recovery, data on symptoms, rhythm, heart rate, blood pressure, and work load in metabolic equivalents (METs) were collected and recorded. ECG was continuously monitored. Blood pressure was measured using the arm-cuff auscultation method immediately before exercise and at peak exercise. rSBP was defined as the ratio of SBP at 3 minutes in recovery to SBP at peak exercise.[10] Additionally, rSBP measured on the first day of admission to the CR Clinic was considered a predictor for the study outcome.

The rehabilitation program started 2 - 4 weeks after CABG for a total duration of 2 months. It was structured as three training sessions per week. Each session took about 60 minutes and consisted of 5 - 10 minutes of warm-up through stretching and 40 - 45 minutes of intermittent aerobic exercise, concluded by approximately 5 - 10 minutes of cooling down.

The main end-point and outcome of the study were post-exercise measures of cardiovascular parameters, including peak heart rate, heart rate recovery, resting blood pressure and maximum blood pressure, peak oxygen consumption, and METs after the completion of 24 rehabilitation sessions, all of which were measured and monitored by a cardiac rehabilitator.

The data are expressed as mean ± SD for the quantitative variables and were summarized by absolute frequencies and percentages for the categorical variables. The categorical variables between the inter-quartile subgroups were compared using the chi-square test and the continuous variables by the one-way analysis of variances (ANOVA) with Tukey's post-hoc test when appropriate.

Multivariable linear regression analyses were used to evaluate the association between baseline rSBP and changes in the study end-points after adjusting for the confounding variables. These variables included sex, age, body mass index, function class (based on the New York heart association [NYHA] functional classification), risk stratification (categorized as the three levels of high-, intermediate-, and low risk according to the American association of cardiovascular and pulmonary rehabilitation risk stratification criteria),[11] and left ventricular ejection fraction. All the analyses were performed using SPSS version 13.0 for Windows (SPSS Inc., Chicago, IL). Statistical significance level was set at p value < 0.05 and all p values are two-sided.

## Results

The study population consisted of 352 patients. The rSBP for each quartile, 1 to 4, was $0.73 \pm 0.10$, $0.83 \pm 0.02$, $0.90 \pm 0.03$, and $0.90 \pm 0.08$, respectively (p value < 0.001). The male to female ratio was different across the groups (Table 1). However, patients in different quartiles had similar overall incidences of known CAD risk factors, function class, and mean left ventricular ejection fraction.

The exercise characteristics according to rSBP are shown in Table 2. Patients in quartile 1 (rSBP ≤ 0.8) were more likely to have higher METs, higher peak SBP, lower resting blood pressure, and higher peak $O_2$ consumption compared to other quartiles based on Tukey's post-hoc analysis. When considering rSBP as a continuous variable, there were negative associations between rSBP and METs value as well as peak SBP and peak $O_2$ consumption, while the linear association between baseline rSBP and rest SBP was positive.

The multivariable linear regression analysis showed that an abnormal baseline rSBP after exercise was a strong

Table 1. Baseline characteristics according to systolic blood pressure recovery after exercise[*]

| | Quartile of systolic BP$_{min\ recovery}$/ systolic BP$_{peak\ exercise}$ | | | | |
| | First quartile (n=119) | Second quartile (n=82) | Third quartile (n=81) | Forth quartile (n=70) | p value |
|---|---|---|---|---|---|
| Male gender | 108 (86.6) | 66 (80.5) | 64 (79.0) | 43 (61.4) | 0.001 |
| Age (y) | 59.8±9.1 | 62.2±9.0 | 62.3±9.0 | 60.9±9.1 | 0.186 |
| Body mass index (kg/m$^2$) | 27.3±3.9 | 26.8±3.5 | 26.4±3.7 | 26.8±4.6 | 0.443 |
| Cigarette smoking | 39 (35.5) | 18 (23.7) | 21 (29.6) | 18 (31.0) | 0.395 |
| Diabetes mellitus | 34 (30.9) | 20 (26.3) | 24 (33.8) | 20 (34.5) | 0.714 |
| Hyperlipidemia | 57 (51.8) | 43 (56.6) | 53 (53.5) | 37 (63.8) | 0.500 |
| Hypertension | 47 (42.7) | 35 (46.1) | 30 (42.3) | 33 (56.9) | 0.302 |
| Family history of CAD | 56 (50.9) | 24 (31.6) | 26 (37.1) | 25 (43.1) | 0.053 |
| Renal failure | 1 (1.0) | 0 | 2 (3.2) | 0 | 0.288 |
| Function class (NYHA) | | | | | 0.013 |
| I | 96 (80.7) | 71 (86.6) | 68 (84.0) | 46 (65.7) | |
| II | 20 (16.8) | 11 (13.4) | 11 (13.6) | 18 (25.7) | |
| III | 3 (2.5) | 0 | 2 (2.5) | 6 (8.6) | |
| Global ejection fraction (%) | 48.4±8.2 | 48.1±8.7 | 48.8±8.2 | 48.4±8.1 | 0.970 |

[*]Data are presented as mean±SD or n (%)

BP$_{min\ recovery}$, Minimum recovery blood pressure; CAD, Coronary artery disease; NYHA, The New York Heart Association

Table 2. Exercise characteristics according to systolic blood pressure recovery after exercise

| | Quartile of systolic BP$_{min\ recovery}$/ systolic BP$_{peak\ exercise}$ | | | | |
| | First quartile (n=119) | Second quartile (n=82) | Third quartile (n=81) | Forth quartile (n=70) | p value |
|---|---|---|---|---|---|
| Peak metabolic equivalent | 8.7±3.8 | 7.7±2.2 | 6.9±2.2 | 6.8±2.6 | < 0.001 |
| Peak heart rate (beat/min) | 130.0±18.5 | 128.4±20.2 | 122.8±19.6 | 126.8±21.3 | 0.098 |
| Heart rate recovery (beat/min) | 116.1±17.9 | 112.5±18.4 | 108.3±21.2 | 110.9±22.7 | 0.070 |
| Peak systolic blood pressure (mmHg) | 145.7±26.0 | 138.0±15.6 | 135.3±14.9 | 117.5±15.5 | < 0.001 |
| Resting systolic  blood pressure (mmHg) | 107.7±17.2 | 114.4±12.3 | 121.1±12.6 | 132.9±17.8 | < 0.001 |
| Peak O$_2$ consumption (%) | 29.9±9.6 | 26.7±7.6 | 24.1±7.8 | 23.3±9.3 | < 0.001 |

[*]Data are presented as mean±SD or n (%)

BP$_{min\ recovery}$, Minimum recovery blood pressure; CAD, Coronary artery disease; NYHA, The New York heart association

predictor of post-CR program exercise parameters, including METs value (β = -0.617, SE = 0.127, p value < 0.001) and peak O$_2$ consumption (β = -1.950, SE = 0.363, p value < 0.001) measured in the last session after adjustment for demographics, function class, and left ventricular ejection fraction.

## *Discussion*

Recently, authors have reported high sensitivity and acceptable specificity of rSBP after exercise for identifying patients with CAD and revealed that it has more benefits for discriminating CAD from normal condition in comparison with ST-segment changes. However, no published data are available about the efficacy of SBP in assessing the results of the CR procedure in those who have undergone CABG. The present study strongly underlines the predictive role of baseline rSBP after exercise in evaluating exercise parameters

following CR. This baseline index can effectively predict abnormal post-exercise METs value, peak O$_2$ consumption, post-exercise heart rate, and heart rate recovery after a 24-session CR program. This finding can also suggest that rSBP may be diagnostically useful for monitoring patients' status during rehabilitation and differentiating those who have disability to continue rehabilitation sessions. Our results were also confirmed when adjustment was made for the patients' age, function class, and baseline exercise indices because changes in SBP vary among individuals with different maximum exercise capacity.[12] It should also be noted that vascular walls tend to become less elastic and stiffer with ageing and some studies have indicated that older individuals exhibit a greater blood pressure response to handgrip exercise than younger ones.[13, 14] Furthermore, SBP at rest does not have enough prognostic value compared to SBP during exercise because a rise in SBP during exercise provides information about the hemodynamic response to increasing physical stress, which may not be obtained from

SBP at rest.[12]

The association between exercise parameters and impaired rSBP can be explained in view of some mechanisms. First, it has been demonstrated that high systemic vascular resistance results in an impaired decrease of SBP from peak exercise to rest. This relationship can be caused by deregulating the sympathetic and vagal systems. SBP may remain elevated longer if the sympathetic tone does not decrease and the vagal tone does not increase during the post-exercise period.[10, 15] In fact, SBP may reduce more after exercise in healthy persons with good fitness than in unfit persons with a high risk of CAD. Therefore, rSBP abnormality on the day of admission to the CR program can predict the unfitness of patients undergoing rehabilitation sessions and thus reflect unbeneficial effects of rehabilitation in these individuals. Another mechanism explaining the pathophysiology of the relationship between rSBP impairment and exercise parameters may be abnormal changes in cardiac output during dynamic exercise during CR. Left ventricular dysfunction reflects a failure to increase cardiac output following exercise training.[16] This failure can affect exercise-induced SBP increasing and therefore reduce the positive effects of CR on patients' $O_2$ consumption and METs value.

Another important finding in our study was the confirmation of the good discriminative power of SBP recovery for assessing post-exercise parameters following CR. Although the value of this index was demonstrated in predicting CAD outcome, its power for assessing the CR outcome has not been determined. Some studies have shown high sensitivity and specificity of SBP recovery,[4] whereas some others have revealed high specificity and not acceptable sensitivity for this measurement.[17] Based on our results, it seems that in terms of accuracy, rSBP measure is comparable with traditional ST segment measures for the assessment of patients' exercise indices.

## Conclusion

Our results strongly emphasize the predictive role of baseline rSBP in evaluating exercise parameters following CR. This baseline index can predict the abnormal measurement of post-exercise METs value, peak $O_2$ consumption, post-exercise heart rate, and heart rate recovery after a 24-session CR program.

## Acknowledgment

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