RESEARCH ARTICLE

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Clinical and Metabolic Factors Associated with Heart Rate Recovery in Patients Undergoing Exercise Stress Testing: A Cross-sectional Study from Southwest Iran

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Abstract

Background and Aim: Heart rate recovery (HRR) after exercise is a simple marker of autonomic function. Attenuated HRR has been linked to increased cardiovascular risk and mortality. This study examined the associations between traditional cardiovascular risk factors, exercise-induced ischemia, and HRR at one minute (HRR1) in a population from southwest Iran.

Materials and Methods: This cross-sectional study included 342 patients (mean age 50.7±10.3 years) referred for Bruce protocol treadmill testing due to non-specific symptoms and clinical suspicion of ischemia. HRR1 was calculated as peak heart rate minus heart rate at one minute after exercise cessation. Bivariate analyses were performed for age, sex, hypertension, diabetes, smoking, high plasma low-density lipoprotein (LDL) cholesterol (>130 mg/dL), family history of coronary artery disease, and exercise-induced ischemia. Variables with $P < 0.25$ were entered into multivariate linear regression. Multicollinearity was assessed using the variance inflation factor, and standard linear regression assumptions were verified.

Results: The mean HRR1 was 31.4±10.4 beats per minute. In multivariate analysis, higher HRR1 was significantly and independently associated with normotension (B=4.52, $P = 0.001$), absence of diabetes (B=3.81, $P = 0.010$), LDL cholesterol ≤130 mg/dL (B=2.67, $P = 0.011$), and a negative exercise test for ischemia (B=3.94, $P = 0.016$). No significant associations were found with age, sex, smoking, or family history of coronary artery disease.

Conclusion: Impaired HRR1was independently associated with hypertension, diabetes mellitus, elevated LDL cholesterol, and exercise-induced ischemia in this population. These findings suggest that HRR1 can serve as a simple, useful integrative marker of cardiovascular risk during routine exercise stress testing. Due to the cross-sectional design, causality cannot be inferred, and prospective studies are warranted.

Keywords: Heart rate recovery, exercise stress test, myocardial ischemia

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INTRODUCTION

Heart rate recovery (HRR), the rate at which heart rate slows down after the termination of exercise, is defined by the parasympathetic recovery along with the withdrawal of the sympathetic branch of the autonomic nervous system.[1] HRR reflects the integrated function of the cardiovascular, respiratory, and metabolic systems, collectively referred to as cardiorespiratory fitness.[1-3]

Lower HRR values have been associated with adverse outcomes, including systemic inflammation, arrhythmia-related mortality,[4,5] hypertension, and insulin resistance.[6,7] Furthermore, established demographic and lifestyle factors such as advanced age,[8] as well as smoking and caffeine consumption,[9,10] have been identified as influential variables in previous studies.

Beyond its established diagnostic utility for detecting ischemia via electrocardiography, exercise stress testing also provides prognostic information through HRR determination, which is of considerable relevance in primary prevention. These dual capabilities continue to be investigated by the scientific community.[2,3]

Objectives

Cardiovascular diseases remain a leading cause of mortality both globally and in Iran. Considering the differences in lifestyle and the varying prevalence of risk factors across regions, the aim of this study was to investigate the relationship between HRR, an important component of cardiovascular risk assessment, and traditional risk factors including age, smoking, diabetes, and hypertension in the Dezful region of western Iran, a population for which such data have not previously been reported.

Notably, this study simultaneously examines the associations of HRR with both traditional risk factors and exercise-induced ischemia a combined assessment that has been infrequently reported in the existing literature. It is expected that the results from the current research will prove helpful in designing effective preventive measures for improved health outcomes in the region.

METHODS

This cross-sectional study was conducted in a specialized cardiac clinic in Dezful, Southwest Iran, between October 2021 and October 2022.

Patients aged 30-70 years who were referred for exercise stress testing due to non-specific symptoms and clinical suspicion of ischemia were eligible for inclusion. Inclusion criteria comprised: no known cardiovascular disease; normal baseline electrocardiogram and echocardiogram; controlled blood pressure (<140/90 mmHg) at the time of testing; and ability to complete the test until reaching the age-predicted maximum heart rate. Patients taking beta-blockers or other medications known to significantly affect heart rate were excluded. Additional exclusion criteria included premature test termination due to chest pain, arrhythmias, or other limiting symptoms, and incomplete HRR data. A total of 342 patients met the inclusion criteria and were enrolled using convenience sampling.

The study protocol was approved by the Institutional Review Board and Ethics Committee of Dezful University of Medical Sciences (approval no: IR.DUMS.REC.1401.086, dated: 17.01.2023). Written informed consent was obtained from all participants after explanation of the study objectives and procedures. Participants were assured of confidentiality and their right to withdraw at any time. The study was conducted in accordance with the Declaration of Helsinki.

Exercise Testing Protocol: Exercise testing was performed using the BPL Dynatrac Neo Stress Test System treadmill according to the standard Bruce protocol, following ACC/AHA recommendations.[11]

Heart rate and blood pressure were recorded at the end of each stage. The exercise testing equipment was regularly calibrated by the center's biomedical engineer, and its proper function was verified before each test.

HRR1 was calculated as peak heart rate minus heart rate measured at the first minute after exercise cessation, with the patient in the standing position. Measurements were performed by trained personnel under the supervision of a cardiologist, according to a standardized protocol.

Data Collection: Demographic and clinical data including age, sex, history of hypertension, diabetes mellitus, smoking status, family history of coronary artery disease (CAD), and low-density lipoprotein (LDL) cholesterol levels were extracted from medical records. Definitions were as follows:

Hypertension: Blood pressure ≥140/90 mmHg on repeated measurements in clinic or use of antihypertensive medication.[11]

Diabetes: Fasting blood glucose ≥126 mg/dL or 2-hour postprandial glucose ≥200 mg/dL or use of antidiabetic medication.[11]

Hypercholesterolemia: Plasma LDL cholesterol >130 mg/dL.[12]

Positive family history: CAD in first-degree male relative <55 years or female relative <65 years.[12]

Smoking: Lifetime consumption of ≥100 cigarettes.[12]

Ischemic response: Defined according to standard electrocardiographic criteria during testing.[11]

Statistical Analysis

Data were analyzed using SPSS version 26. Continuous variables are presented as mean ± standard deviation, and categorical variables as frequency (percentage). The Kolmogorov-Smirnov test was used to assess normality. Pearson correlation and independent t-tests (or analysis of variance) were applied for bivariate analyses. Variables with $P < 0.25$ in bivariate analysis were considered for inclusion in the multivariate linear regression model. This liberal threshold was selected given the exploratory nature of the study in a specific regional population, to reduce the risk of prematurely excluding potentially relevant variables.

Prior to regression, assumptions of linear regression were verified, including linearity, homoscedasticity, normality of residuals, and independence of errors. Multicollinearity was assessed using the variance inflation factor; all values were below 2.0, indicating no significant multicollinearity. A *P*-value < 0.05 was considered statistically significant in the final model. All beta coefficients are unstandardized unless otherwise specified.

RESULTS

Study Population

As shown in Table 1, a total of 342 patients were included in this study. The mean age was 50.7±10.3 years, and 182 (53.2%) were male. The mean HRR at one minute (HRR1) was 31.4±10.4 bpm.

The prevalence of cardiovascular risk factors was as follows: hypertension in 131 patients (38.3%), diabetes mellitus in 55 (16.1%), smoking history in 57 (16.7%), positive family history of CAD in 68 (19.9%), and LDL cholesterol >130 mg/dL in 133 (38.9%). A positive exercise test for ischemia was observed in 21 patients (6.1%). Seventy-one participants (20.8%) had no cardiovascular risk factors (not mentioned in the table).

Lower HRR1 values were significantly associated with the presence of hypertension, diabetes mellitus, elevated LDL cholesterol, and a positive exercise test for ischemia. No statistically significant associations were observed between HRR1 and age (r=-0.09, $P = 0.11$), sex, smoking status, or family history of CAD.

Multivariate Analysis

Variables with $P < 0.25$ in the bivariate analysis were entered into the multivariate model (Table 2). The final model included age, hypertension, diabetes mellitus, LDL cholesterol level, and exercise test result. The "number of risk factors" variable was not included in the regression model to avoid conceptual redundancy and multicollinearity with the individual risk factors.

All regression assumptions were satisfied (linearity, homoscedasticity, normality of residuals, and no significant multicollinearity). Beta coefficients reported below are unstandardized.

Table 1. The relationship between hypertension, diabetes, plasma LDL, and the result of the exercise test with heart rate recovery

Variable	Category	No (%)	Heart rate recovery, mean ± SD	*P*-value
Blood pressure	High	131 (38.3)	28.5±10.14	0.01
	Normal	211 (61.7)	33.15±10.13	
Diabetes	Yes	55 (16.1)	28.33±11.66	0.03
	No	287 (83.9)	31.96±10.17	
LDL level	LDL >130 mg/dL	133 (38.9)	30.2±11.1	0.01
	Normal	209 (61.1)	32.13±9.82	
Exercise test	Positive for ischemia	21 (6.1)	29±12.29	0.03
	Negative	321 (93.9)	31.5±10.23	
Smoking	Positive	57 (16.7)	30.33±10.27	0.41
	negative	285 (83.3)	31.59±10.39	
Family history of CAD	Positive	68 (19.9)	32.9±11.61	0.21
	Negative	274 (80.1)	31±10.02	
Sex	Male	182 (52.2)	31.25±10.19	0.81
	Female	160 (46.8)	31.52±10.59	

LDL: Low-density lipoprotein, CAD: Coronary artery disease, SD: Standard deviation

Table 2. Multiple linear regression analysis of factors associated with heart rate recovery

Variable	B (unstandardized)	SE	β (standardized)	t	*P*-value	95% CI for B
Age (years)	-0.38	0.26	-0.09	-1.46	0.145	-0.89 - 0.13
Normotensive (vs. hypertensive)	4.52	1.12	0.22	4.04	0.001	2.32 - 6.72
Non-diabetic (vs. diabetic)	3.81	1.48	0.14	2.57	0.010	0.90 - 6.72
LDL ≤130 mg/dL (vs. >130)	2.67	1.05	0.13	2.54	0.011	0.60 - 4.74
Negative exercise test (vs. positive)	3.94	1.62	0.11	2.43	0.016	0.75 - 7.13
Constant	38.76	3.45	-	11.24	0.001	31.97 - 45.55

LDL: Low-density lipoprotein, CAD: Coronary artery disease, CI: Confidence interval, SE: Standard error

DISCUSSION

This study demonstrated significant associations between lower HRR1 and several major cardiovascular risk factors, including hypertension, diabetes mellitus, elevated LDL cholesterol, and the presence of exercise-induced ischemia, in patients from southwest Iran. An inverse association with age was observed in the bivariate analysis; however, this relationship did not remain statistically significant in the multivariate model. No significant associations were found with sex, smoking history, or family history of CAD.

Our findings regarding hypertension, diabetes, and dyslipidemia are consistent with previous reports. For instance, Sydó et al.[3] followed over 20,000 patients and observed that slower HRR was associated with older age, diabetes, hypertension, obesity, and smoking, whereas sex showed no statistically significant effect on HRR levels. Similarly, Hughes and Chaturvedi[13] reported inverse associations between HRR and systolic blood pressure, blood glucose, and body mass index. Grad and Zdrenghea[11] also noted associations between reduced HRR1 and older age, male sex, high plasma triglycerides, and ischemic response during exercise testing. In some prior studies, reduced HRR was significantly related to both cardiac and non-cardiac mortality.[3] However, the association between HRR and mortality was not evaluated in our study, as such an analysis requires large cohort studies.

The present results align with these studies regarding most metabolic risk factors and extend them by providing data from an Iranian population in the Dezful region. More than one-third of the individuals in the study area had hypertension and elevated LDL cholesterol, which warrants attention in primary prevention health programs in the region.

In the study by Ulleryd et al.,[14] an association between autonomic dysfunction and carotid plaque and cardiac inflammation was observed. Our research demonstrated a significant correlation between low HRR and exercise-induced ischemia, which is consistent with the findings of Ulleryd et al.[14] and Grad and Zdrenghea.[11]

This possible association may not be limited to overt ischemia, as the literature suggests that reduced HRR values have also been observed in cases of silent ischemia or microvascular disease, even in the presence of normal stress testing.[15,16]

Given the possibility of cardiac ischemia in the presence of low HRR, the routine use of this parameter in sports centers for ischemia screening is more prominently recommended.

Previous research has suggested that men tend to have higher fitness levels than women across all age groups, possibly due to higher haemoglobin levels, greater muscle mass, and higher cardiac output.[16,17]

Furthermore, a study by Beltrame et al.[18] observed that estradiol levels in women of all ages may play a role in HRR and autonomic nervous system response. In 2021, Zubac et al.[19] indicated that the HR recovery rate continuously declined with age in both males and females. However, in a very comprehensive study by Jackson et al.,[8] the HR recovery rate decreased in association with age (primarily due to reduced sympathetic response), but the pace of decline hastened beyond the age of 45 years. Nevertheless, lower body mass index, greater levels of physical activity, and being a non-smoker attenuated the reductions in fitness levels and HR recovery rate associated with aging.[8] The lack of a significant association between age and HRR1 in the multivariate analysis differs from some earlier reports. This discrepancy may be related to the relatively narrow age range of our sample (30-70 years), sample size, or unmeasured genetic and environmental factors specific to this population.[20,21]

The absence of sex differences in HRR1 is consistent with some prior investigations that found no clear gender effect after adjusting for other variables.

Previous studies have shown a link between smoking and decreased HRR, and autonomic dysfunction has been identified as the underlying cause.[22,23]

Likewise, the non-significant association with smoking, despite lower mean HRR1 values among smokers, could be attributed to the modest number of smokers (16.7%) and variations in smoking intensity and duration that were not captured in this study. While previous studies have described these relationships, The present study uses regional data from southwestern Iran, where cardiovascular risk profiles and lifestyles differ across populations. The results of the above studies suggest that HRR1 may serve as a useful integrative marker associated with traditional risk factors and cardiac ischemia and could be applied in clinical practice.

Study Limitations

Several limitations should be considered when interpreting these findings. First, the cross-sectional design allows only for the identification of associations and does not permit conclusions about causality or temporal relationships. Second, this was a single-center study conducted in one cardiac clinic in Dezful, which may limit generalizability. Although participants were classified as asymptomatic, they were referred to a cardiac clinic for ischemia evaluation, indicating a clinical suspicion that may not represent the general healthy population. Third, this referral pattern introduces potential selection bias, and the results may not fully represent asymptomatic community-dwelling individuals. Due to the relatively small sample size (n=342) and the low prevalence of certain factors—such as smoking (16.7%) and positive ischemic response (6%) the study may have been underpowered to detect statistically significant associations for these specific variables. Additionally, objective measures of cardiorespiratory fitness, such as VO_2max or METs, were not available, as gas exchange analysis was not performed. We did not collect detailed information on physical activity levels, dietary patterns common in the Western Iran region, educational level, socioeconomic status, or caffeine consumption, all of which could act as residual confounders. Medication history was limited to the exclusion of beta-blockers, and other drugs potentially affecting autonomic function were not fully stratified. Heart rate was recorded manually from the monitor screen at exactly one minute, a method susceptible to minor human error or equipment lag compared to automated digital beat-to-beat analysis. HRR was measured in a standing position; different recovery postures (e.g., supine or active cool-down) significantly alter parasympathetic reactivation, potentially limiting the comparability of these results to studies using different protocols. Finally, no formal sample size or power calculation was performed, as this was a convenience sample. Despite these limitations, the integration of HRR as an inexpensive and practical risk stratification tool after exercise testing is recommended. However, large-scale, cohort-based complementary studies are still needed.

CONCLUSION

This cross-sectional study showed that impaired HRR1 is significantly associated with hypertension, diabetes mellitus, high LDL cholesterol, and exercise-induced ischemia among patients undergoing treadmill testing in Southwest Iran. HRR1 appears to be a simple and practical physiological marker associated with cardiovascular risk profiles in routine exercise stress testing. Due to the associative nature of the findings and the limitations inherent in the study design, larger prospective studies are needed to further evaluate the clinical utility of HRR1 in diverse populations and to explore its relationship with long-term cardiovascular outcomes and primary prevention

Ethics

Ethics Committee Approval: The study protocol was approved by the Institutional Review Board and Ethics Committee of Dezful University of Medical Sciences (approval no: IR.DUMS.REC.1401.086, dated: 17.01.2023).

Informed Consent: Written informed consent was obtained from all participants after explanation of the study objectives and procedures.

Footnotes

Authorship Contributions

Surgical and Medical Practices: H.S., M.K., A.K., M.H., S.S., Concept: H.S., M.K., A.K., M.H., S.S., Design: H.S., M.K., A.K., M.H., S.S., Data Collection or Processing: H.S., M.K., A.K., M.H., Analysis or Interpretation: H.S., M.K., A.K., M.H., Literature Search: H.S., M.K., M.H., S.S., Writing: H.S., M.K., A.K., M.H., S.S.

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