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Relationship between heart rate recovery after exercise and maximal oxygen uptake in sedentary patients with type 2 diabetes

Original article

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ABSTRACT

AIMS: Heart rate recovery after exercise (HRR) is an estimate of autonomic modulation of the heart, and has been shown to be inversely associated with type 2 diabetes. Type 2 diabetes is associated with decreased maximal oxygen consumption (VO_2max). Aim of our study was to assess the relationship between HRR and VO_2max in sedentary patients with type 2 diabetes.

METHODS: Maximal exercise testing to determine VO_2max (ml · Kg^{-1} · min^{-1}) was performed in 16 sedentary patients with type 2 diabetes (DP) and in 16 age-matched sedentary healthy controls (HS). HRR (bpm) 2 min after cessation of the exercise was recorded. Simple linear regression was used to assess the relations between HRR and VO_2max.

RESULTS: VO_2max and HRR were significantly lower in DP compared to HS (P = 0.002 and P = 0.008 respectively). A correlation between HRR and VO_2max has been found, stronger in DP (r = 0.672, P = 0.004) than HS (r = 0.620, P = 0.01).

CONCLUSIONS: Our study suggests that regular physical activity aimed to improve the levels of VO_2max in subjects with diabetes may improve the HRR and reduce the risk of cardiovascular events.

Key words: Autonomic nervous system; Diabetes, HRR; Physical activity; VO_2max

INTRODUCTION

Heart rate recovery (HRR) is the rate at which heart rate decreases, usually within minutes, after moderate to heavy exercise, and is regulated by autonomic nervous system [1]. HRR immediately after exercise is a marker of parasympathetic function that has been shown to be inversely associated with insulin resistance, metabolic syndrome, and type 2 diabetes [2]. Attenuated HRR following maximal exercise testing is an important predictor of mortality in healthy adults [3], in patients with cardiovascular disease [4] and with diabetes [5].

The recent "Look AHEAD" study [6] suggested that lifestyle intervention aimed to improve cardiovascular fitness, defined as the estimated metabolic equivalent level based on the treadmill work load, has a beneficial effect upon autonomic nervous system function as reflected in the improvement of heart rate recovery after exercise in adults with type 2 diabetes. However, that study did not analyze changes in maximal oxygen consumption (VO_2max), which is considered the best measure of overall cardiorespiratory fitness and an important predictor of cardiovascular and all-cause mortality [7], and its relationship with HRR.

Previous studies have shown that HRR is related to VO_2max in athletes [8,9], but to our knowledge there are no studies that have investigated this relationship in sedentary type 2 diabetic patients.

Aim of our study was to assess the relationship between HRR measured 2 min after peak of exercise, as index of autonomic nervous function, and VO_2max, as index of cardiovascular fitness, in sedentary patients with type 2 diabetes.

METHODS

We recruited sixteen (eight male and eight female) patients with type 2 diabetes (DP) and sixteen (nine male and seven female) healthy subjects (HS). They were aged 40 to 70, and were classified sedentary according the criteria of the International Physical Activity Questionnaire (IPAQ) [10]. All DP were being treated with diet and antiglycemic agents. Significant cardiovascular disease was excluded in all subjects by an instrumental examination. Each subject gave written informed consent to participate, following an explanation of the nature and purpose of the study. The procedures were conducted in compliance with the Declaration of Helsinki and were approved by the IRB Committee at our Institution. All the physiological evaluations were performed at the Laboratory of Sport and Exercise Sciences "DISMOT" Research Unit of the University of Palermo, Italy.

All tests were performed between 8 and 10 a.m., after a 12-h overnight fast. Stature and body mass were measured before starting the tests using a stadiometer and an electronic weighing scales respectively (SECA, Germany). All subjects performed a graded exercise test to exhaustion on treadmill, according standard and modified Bruce protocols. The test was stopped when one or more of the following criteria were met: attainment of a VO_2max plateau < 2.2 ml · Kg^{-1} · min^{-1}; respiratory exchange ratio (RER) > 1.10; maximal heart rate (HRmax) close to theoretical value of 220-age; the subject was unable to maintain the required work rate.

A disposable facemask with a 50-80ml dead space (Cosmed V2, Cosmed Srl, Italy) was used to collect expired air throughout the test. Oxygen uptake (VO_2) was recorded with a breath-by-breath measurement system (Cosmed Quark CPET, Cosmed Srl, Italy) and maximal oxygen uptake (VO_2max) was defined as the highest consecutive 30-s average value achieved during the test. The flow meter and gas analyzers were calibrated before each test, according to the manufacturer's instructions.

During the tests the heart rate of each participant was recorded using a short-range radio telemetry system (Polar Electro Oy, Finland). Heart rate recovery (HRR) was defined as the difference between heart rate at peak exercise and heart rate 2 minutes after cessation of the exercise (Figure 1).

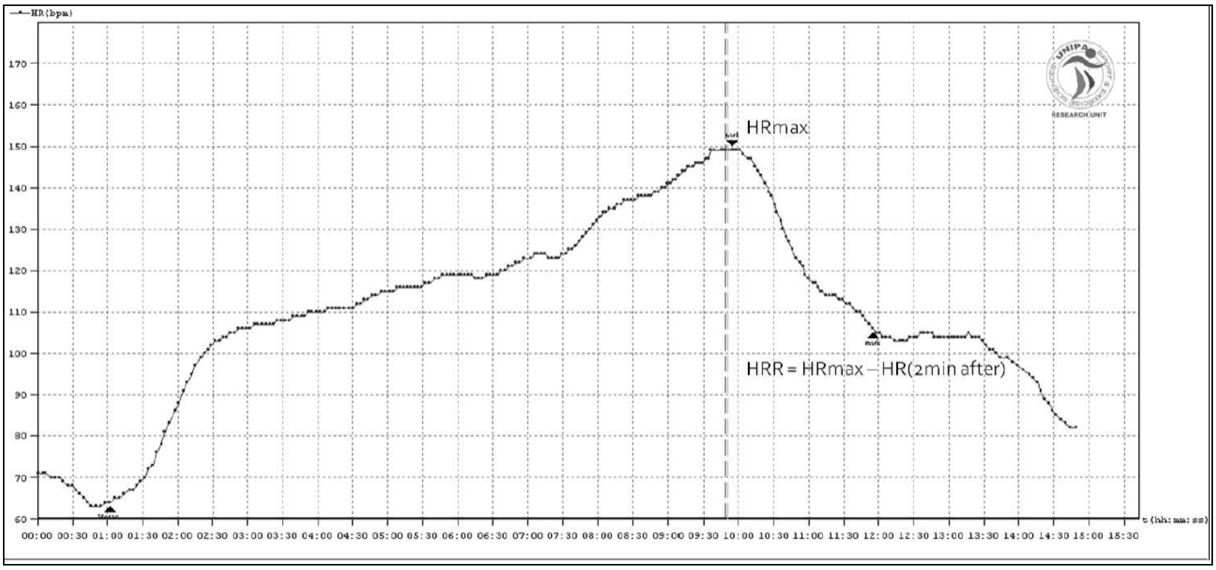

Figure 1. Representative data showing heart rate (HR) during exercise test. HRmax and HRR are indicated.

The cool-down period after cessation of exercise consisted of walking on treadmill at 2.0 Km/h of speed and 0% of grade. An abnormal heart rate recovery was defined as a value of ≤ 22 beats per minute (bpm) at 2min after exercise [11]. All responses were monitored and grafically displayed throughout rest, exercise, and cool-down.

Data are presented as means ± standard deviation (SD). Differences between groups were assessed with two-tailed Student's *t*-test for unpaired data. A simple linear regression model was used to assess the relations between HRR and VO_2max. Pearson product moment correlation coefficient (*r*) was used to determine the association between the considered parameters. The *P* value less than 0.05 was considered statistically significant.

RESULTS

The characteristics of subjects are shown in Table 1. The two groups were similar in age and body weight. BMI was higher in DP (29.9 ± 3.2 vs. 26.9 ± 4.2, *P* = 0.03). At rest, HR and VO_2 were similar in both groups.

Table 1: Characteristics of patients with type 2 diabetes (DP) and healthy subjects (HS) (means ± SD).

	DP (*n* = 16)	HS (*n* = 16)	P-value
Age (y)	57 ± 7.5	53 ± 6.9	0.100
Body height (cm)	165 ± 7.7	166 ± 9.8	0.826
Body weight (Kg)	81 ± 9.4	74 ± 15.5	0.136
BMI ($Kg \cdot m^{-2}$)	29.9 ± 3.2	26.9 ± 4.2	0.033 *
HRrest (bpm)	74 ± 12.1	74 ± 12.8	0.899
HRmax (bpm)	130 ± 16.1	143 ± 13.5	0.024 *
VO_2rest ($ml \cdot Kg^{-1} \cdot min^{-1}$)	3.78 ± 1.2	3.63 ± 0.9	0.703
VO_2max ($ml \cdot Kg^{-1} \cdot min^{-1}$)	20.6 ± 4.3	28.2 ± 8.1	0.002 **
HRR (bpm)	28 ± 8.4	37 ± 8.9	0.008 **

*Difference between DP and HS: * Significant (P < 0.05), ** Very significant (P < 0.01).*
BMI, body mass index; HR, heart rate; VO_2, oxygen uptake; HRR, heart rate recovery.

Termination of exercise was due to volitional fatigue for all subjects and no subject demonstrated abnormal physiological response to exercise. HRmax was significantly lower in DP than in HS (130 ± 16.1 vs. 143 ± 13.5 bpm; *P* = 0.024). VO_2max was significantly lower in DP compared to HS (20.6 ± 4.3 vs. 28.2 ± 8.1 $ml \cdot Kg^{-1} \cdot min^{-1}$, *P* = 0.002).

HRR was significantly lower in DP (28 ± 8.4 vs. 37 ± 8.9 bpm, *P* = 0.008). An abnormal value (HRR < 22 bpm) was found only in 4 DP (25%).

When linear regression analysis was performed, a significant positive correlation between HRR and VO_2max has been found in both DP (Figure 2) and HS (Figure 3) (*r* = 0.672, *P* = 0.004 and *r* = 0.620, *P* = 0.01 respectively).

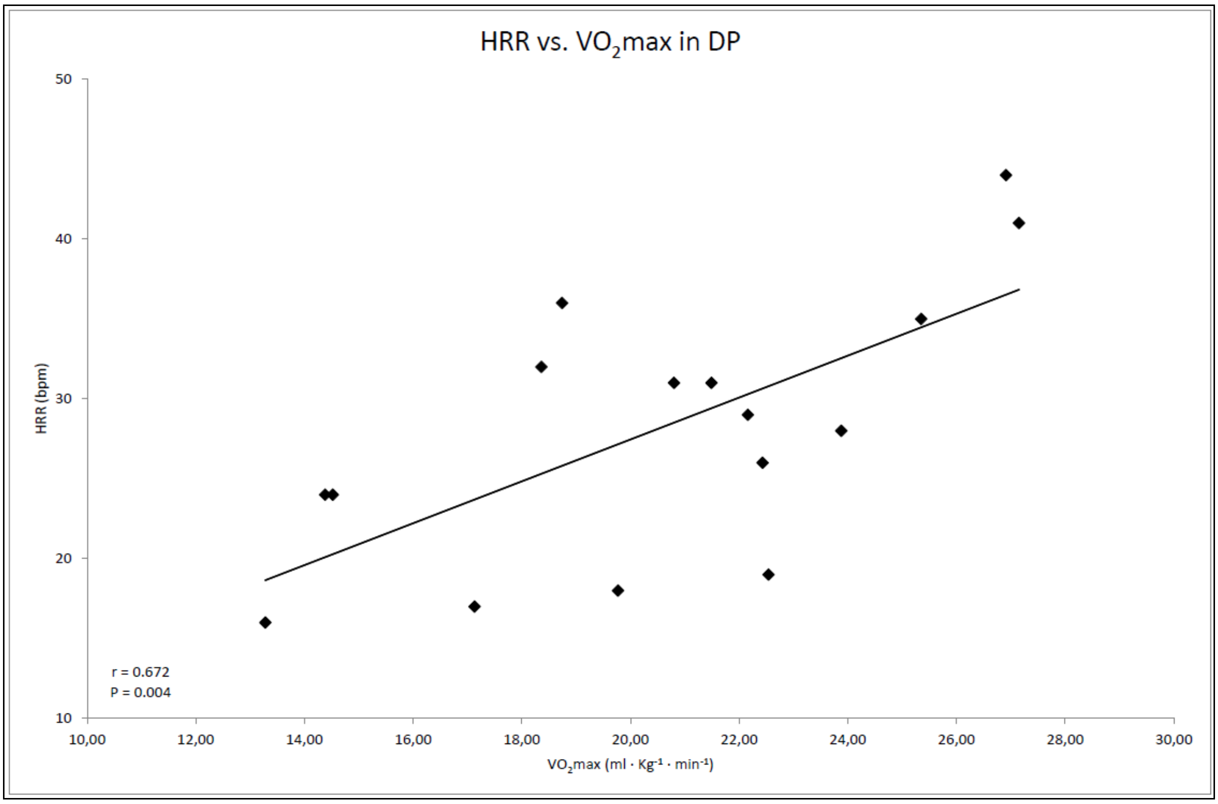

Figure 2. Correlation between heart rate recovery (HRR) and maximal oxygen uptake (VO2max) in patients with diabetes (DP).

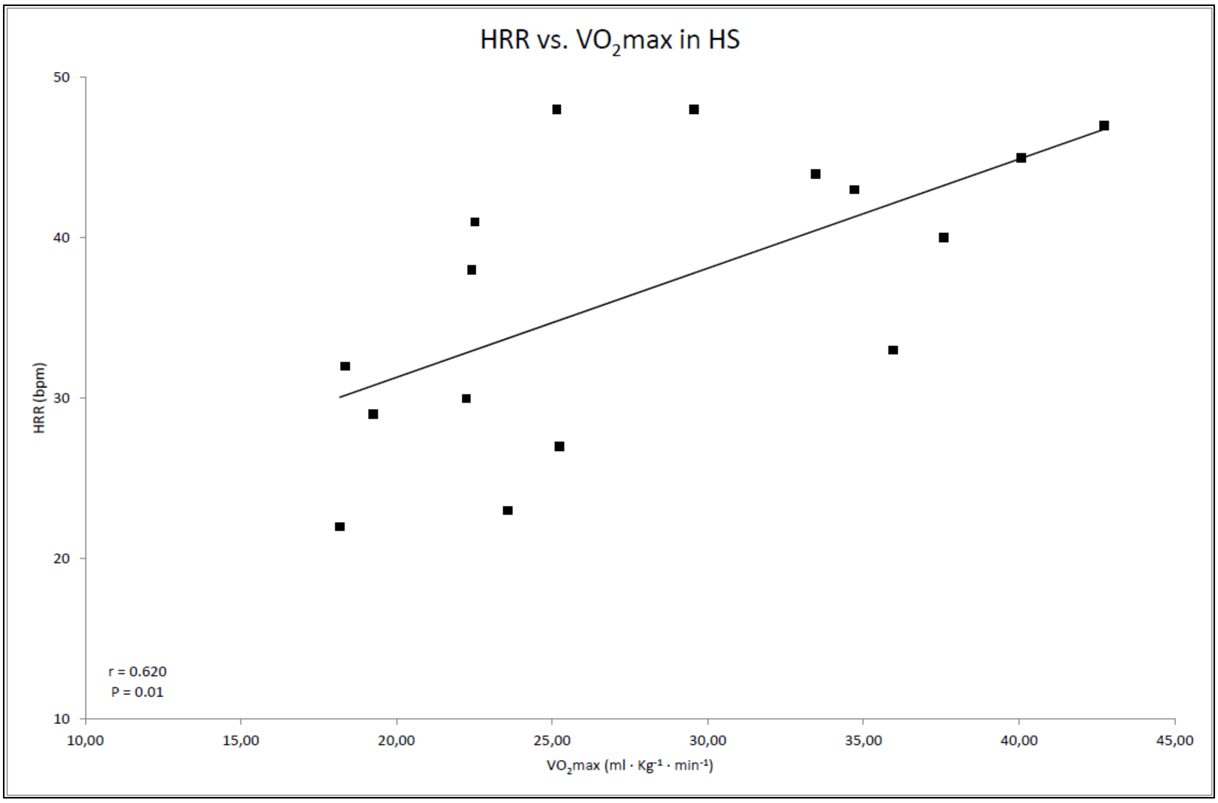

Figure 3. Correlation between heart rate recovery (HRR) and maximal oxygen uptake (VO2max) in healthy subjects (HS).

DISCUSSION

The heart rate recovery immediately after exercise is considered to be a function of the autonomic nervous system, and a consequence of parasympathetic reactivation and sympathetic withdrawal [11]. Several studies have identified the reduced HRR as a predictor of cardiovascular and all-cause mortality in patients referred for exercise testing [3,12], in patients with cardiovascular disease [4,13,14], and in patients with diabetes [5]. It has been shown that HRR is reduced in individuals with diabetes and with impaired fasting glucose levels [15], and that the development of abnormal HRR is indicative of autonomic dysfunction even in pre-diabetic subjects [2]. The recent "Look AHEAD" study [6] suggested that lifestyle intervention aimed to improve cardiovascular fitness has a beneficial effect upon autonomic nervous system function as reflected in the improvement of heart rate recovery after exercise in adults with type 2 diabetes.

In our study we evaluated the VO_2max, which is considered the best measure of overall cardiorespiratory fitness and an important predictor of cardiovascular and all-cause mortality [7], and its relationship with HRR after exercise in sedentary patients with type 2 diabetes.

In our study the mean value of VO_2max was significantly lower in DP compared to HS (20.6 ± 4.3 vs. 28.2 ± 8.1 ml $\cdot Kg^{-1} \cdot min^{-1}$, $P = 0.002$); this finding is consistent with the observation that sedentary patients with diabetes have decreased physical fitness, as measured by VO_2max, compared to similarly sedentary healthy subjects [16]. HRR after exercise was significantly lower in DP compared to HS (28 ± 8.4 vs. 37 ± 8.9 bpm, $P = 0.008$) and a significant correlation with VO_2max is showed in both DP and HS ($r = 0.672$, $P = 0.004$ vs. $r = 0.620$, $P = 0.01$). This correlation was stronger in DP, despite of their lower levels of VO_2max, compared to HS , so that we can assume that the exercise-induced muscle and cardiovascular adaptations resulting in an increase in VO_2max (e.g., increased muscle capillarizzation, increased blood flow and cardiac output, alterations in the symphato-vagal balance and changes in substrate utilizzation) improve the efficiency of the metabolic processes and contribute to increase HRR after exercise, especially in subjects with low levels of physical fitness.

Therefore, the reduction of HRR may reflect not only the imbalance of the autonomic system, but also the decreased physical fitness demonstrated in our study by the reduced values of VO_2max.

Regular physical activity that allows to increase the levels of VO_2max may improve HRR and reduce the risk of cardiovascular events in patients with diabetes.

CONCLUSIONS

Heart rate recovery after exercise may be considered an index of physical fitness, and exercise testing with measurements of HRR is an useful tool for the assessment of the combination of cardiovascular fitness and autonomic function.

In sedentary patients with type 2 diabetes regular exercise aimed to increase VO_2max has also a beneficial effect on the function of the autonomic nervous system which is reflected in the improved HRR.

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