Original Article

Physiological and emotional influence on heart rate recovery after submaximal exercise

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ABSTRACT

The purpose of this study was to assess the role of cardiovascular fitness and emotional state in heart rate recovery after submaximal exercise. Fifty recreationally active subjects (male n=19, females n= 31) completed the study. Height, weight, body composition, and waist circumference were measured, with current emotional state assessed through completion of the Profile of Mood States questionnaire, followed by the Queen's College Step Test to estimate maximal oxygen consumption (VO_2max). Heart rate recovery was determined by the difference between assessments of peak heart rate during exercise and 1 minute post-exercise. Heart rate recovery was correlated with VO_2 max, body composition, body mass index, waist circumference, resting heart rate, peak heart rate and the assessed mood states. A moderate negative correlation was found between heart rate recovery and resting heart rate (r = -.307, p = .032) and was the only variable to show significance. The results of this study disagree with previous literature as only one physiologic variable had a significant relationship with heart rate recovery. This may be because the participants recruited for this study were of at least average fitness and there were no significant signs of psychological stress in study participants at the time of testing. **Key words:** STEP TEST, PSYCHOLOGICAL STRESS, SYMPATHETIC NERVOUS SYSTEM, PARASYMPATHETIC NERVOUS SYSTEM

Cite this article as:
Bunn, J., Manor, J., Wells, E., Catanzarito, B., Kincer, B. & Eschbach, L.C. (2017). Physiological and emotional influence on heart rate recovery after submaximal exercise. *Journal of Human Sport and Exercise, 12*(2), 349-357. doi:10.14198/jhse.2017.122.11

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Submitted for publication February 2017
Accepted for publication June 2017
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2017.122.11

INTRODUCTION

Heart rate recovery (HRr) reflects the rate at with heart rate (HR) returns to baseline resting values after exercise (Shetler et al., 2001; Yilmaz et al., 2013). HRr has been shown to provide prognostic implications (Patel et al., 2014) for the heart's autonomic function, risk for cardiovascular disease, or other disorders; while providing a non-invasive measurement for predicting future cardiac events (Lauer, 2011) and mortality (Duarte, Myers, & de Araujo, 2015; Jolly, Brennan, & Cho, 2011; Ritt et al., 2012). Abnormal HRr has been associated with certain cardiovascular diseases, with the primary impetus stemming from an impaired parasympathetic nervous system (Piotrowicz, Baranowski, Piotrowska, Zielinski, & Piotrowicz, 2009) or dysfunction of the heart from disease (Patel et al., 2014; Pourmoghaddas, Moghaddasian, Garakyaraghi, Nezarat, & Mehrabi, 2013; Yilmaz et al., 2013).

During exercise, HR increases from heightened sympathetic activity and depressed parasympathetic activity (Tulumen et al., 2011), along with increased stroke volume and cardiac output (Yilmaz et al., 2013). After exercise, reactivation of the parasympathetic system stimulates recovery, driving the rate of HRr, theoretically through vagal tone (Shetler et al., 2001). Training improves cardiac output and increased baroreceptor sensitivity (Barak et al., 2011), decreasing sympathetic response, and reducing HR during recovery. These physiologic processes should improve HRr as fitness levels improve; yet, research on HRr and fitness level has provided mixed results (Buchheit & Gindre, 2006; Buchheit et al., 2008; Buchheit, Simpson, Al Haddad, Bourdon, & Mendez-Villanueva, 2012; Carroll, Marshall, Ingle, & Borkoles, 2012; Lee & Mendoza, 2012; Piotrowicz et al., 2009).

Several factors have been suggested to play a role in HRr. Some of these factors are related to health and fitness, and have been linked to decreased HRr, such as increased maximal oxygen consumption (VO_2max) (Buchheit & Gindre, 2006; Lee & Mendoza, 2012), low resting HR (Barak et al., 2011; Lauer, 2011), low body mass index (BMI) (Carroll et al., 2012; Esco, Williford, & Olson, 2011; Simhaee et al., 2013), and/or low waist circumference (Esco et al., 2011; Lee & Mendoza, 2012). Resting HR has been shown to negatively correlate with life expectancy; where a lower resting HR indicates longer life expectancy (Lauer, 2011). With resting HR providing an indication for level of fitness and mortality, it would seem logical that HRr would also be affected by improved fitness (Lee & Mendoza, 2012). Physical activity participation has also been shown as a predictor of HRr and VO_2 max (Barak et al., 2011; Buchheit & Gindre, 2006; Buchheit et al., 2008; Buchheit et al., 2012; Lee & Mendoza, 2012). Improvements in HRr is part of a training effect with participation in exercise-based rehabilitation programs as shown in subjects with obesity and chronic disease (Carroll et al., 2012; Georgiopoulou et al., 2012; Jin, Jiang, Wei, Chen, & Ma, 2013; Miossi et al., 2012). Further, a comparison between fit and unfit non-obese males found significant correlation between HRr and training load, but no relationship between HRr and VO_2max (Buchheit & Gindre, 2006). Another measure of fitness that may be related to HRr is body composition. Significant correlations have been found between body composition and HRr, showing that individuals with poor body composition tend to have slower HRr (Esco et al., 2011; Simhaee et al., 2013). However, those with poor body composition can improve their HRr through exercise (Carroll et al., 2012). The influences of body composition and fitness on HRr are significant, but are in need of a standardized methodology to accurately define the fitness level and body composition necessary for a favorable HRr value.

While the autonomic nervous system is influenced and trained through improved fitness, one's acute emotional state prior to exercise may also affect performance. In sport and exercise environments, sport–specific tests like the Profile of Mood States (POMS) test can provide accurate and reliable measures of personality characteristics (Weinberg & Gould, 2011). Previous studies have found that emotions can improve from the mood-boosting effects of exercise (Beedie, Terry, & Lane, 2000; Pronk et al., 1995; Schmikli, De Vries, & Backx, 2010), but there is also evidence that the quality of exercise can be affected by mood prior to exercise (Weir, 2011). The POMS questionnaire is sensitive to differences in workload and recovery in trained rowers, as demonstrated by a study that found fatigue scores changed proportionally with high levels of training and insufficient recovery time (Schmikli et al., 2010). The application of the POMS test prior to physical activity allows for an assessment of how varying emotional states can affect quality of performance.

Heart rate recovery can and has been used as predictive tool for mortality, but there is currently no standard method for its assessment and evaluation. It is therefore necessary to validate the use of HRr and its predictive value with regard to cardiovascular fitness (Currie, Rosen, Millar, McKelvie, & MacDonald, 2013; Lee & Mendoza, 2012), body composition (Esco et al., 2011), and testing methodologies (Duarte et al., 2015; Lauer, 2011). The purpose of this study was to assess relationships between HRr and cardiovascular fitness, body composition, and participant's mood state during and after submaximal exercise.

MATERIAL AND METHODS

Participants

The participants for this study included 50 volunteers, 19 males and 31 females, ranging in age from18 to 60 with a mean age of 23.2 ± 21.8 years. Subjects were recruited from the general population through the use of word of mouth and posted flyers. Volunteers were only considered for this study if they were recreationally active; meeting the American College of Sports Medicine's minimal requirements of physical activity and low risk for cardiovascular disease (Pescatello et al, 2014). Prior to experimental trials each participant completed university-approved documents.

Measures

Participant Anthropometrics

Height, mass, waist circumference, and body mass index were measured using standard procedures. Resting blood pressure was measured using a widely available sphygmomanometer and read by a trained clinician, and reported as systolic and diastolic blood pressures. Height, mass, waist circumference, and blood pressure were reported in centimeters, kilograms, centimeters, and mmHg, respectively. Body mass index was calculated using patient height and mass and reported in kilograms/meter^2. Body composition was measured using bioelectrial impedance with an InBody 570 (BIOSPACE, Cerritos, CA). Measurements were reported in percent body fat

Heart Rate

The participant's HR was measured using a Polar chest strap HR monitor (Polar Electro Oulu, Finland). Heart rate was measured throughout exercise with specific measurements taken at rest, at the peak of exercise, and at 15 seconds and 1 minute post-exercise. All measures were recorded and reported in beats per minute. Heart Rate Recovery was assessed as the difference between the 1-min post-exercise HR and peak HR, as recorded by the Polar heart rate monitor.

VO_2 Max

Participant VO_2max was calculated for each participant based on their gender (equations 1 and 2), and using the heart rate obtained at 15 seconds post-exercise.

$$Equation\ 1\ (males):\ VO_2max = 111.3 - (0.42 * HR)$$
$$Equation\ 2\ (females): VO_2max = 65.81 - (0.1847 * HR)$$

Profile of Mood States

The Profile of Mood States (POMS) is a standardized test assessing mood state using the ranged subscales of vigor (-32-0), tension (0-36), fatigue (0-28), confusion (0-28), anger (0-48), and depression (0-60). These are considered to be mood factors that remain stable in a variety of situations, as well as in response to exercise (Bourgeois et al., 2010; Mackenzie, 2001; Pronk et al., 1995). These scores are summed to determine the total mood disturbance (-32-200) of the participant (Weinberg & Gould, 2011). A high negative number for total mood disturbance signifies a good mood disturbance (happy or excited), a high positive number signifies a bad mood disturbance (angry or sad), and the closer the number was to zero, the less disturbed the participant was by their mood. The POMS questionnaire (Mackenzie, 2001) was administered to each participant, electronically, prior to performing the Queen's College Step Test (QCST).

Procedures

This study implemented the QCST, as it provided a submaximal estimation of VO_2 max, and has been utilized in populations of varying fitness levels (Bandyopadhyay, 2008; McArdle, Katch, Pechar, Jacobson, & Ruck, 1972); and the unabbreviated POMS questionnaire was used to determine the participant's acute mood state prior to testing (McNair, 1971).

To determine resting HR, subjects remained seated for several minutes until their HR stabilized. After resting HR was established the participant began the QCST. Participants stepped for three minutes onto a step of 41.3 cm, and to the beat of a metronome set at 96 bpm for males and 88 bpm for females (Zwiren, Freedson, Ward, Wilke, & Rippe, 1991).

Analysis

Pearson correlation was performed using HRr as the dependent variable and with the following independent variables: VO_2max, percent body fat, waist circumference, BMI, categorical mood state (as measured by scores retrieved from each subscale of the POMS questionnaire), peak HR and resting HR. Data analysis was done using SPSS (Chicago, IL) with an *a priori* alpha level of 0.05.

RESULTS

Final statistical analysis included only 49 participants, as one male participant scored very high in several of the POMS categories, indicating a large mood disturbance for fatigue, confusion, and depression. This participant was a statistical outlier, and was therefore removed from the analyses.

Analysis of participant demographics relative to HRr, blood pressure, and resting HR indicated the study population was of average fitness and health (Table 1). The body composition, waist circumference, and estimated VO_2 max values were also near average for both genders (Table 1). Notably, BMI for the males would be classified as overweight, but waist circumference and body composition values remained low.

Table 1. Participant Means, Standard Devations, and Pearson Correlations

	Females (n=31)	**Males (n=19)**	**Total**	**R-value**
Mass [kg]	64.9 ± 9.4	86.3 ± 9.0	72.7 ±13.9	-
Height [cm]	164 ± 9.9	179.6 ± 11.5	169.7 ±12.9	-
Age [y/o]	21.9 ± 5.0	25.5 ± 9.5	23.2 ± 7.1	-
HR rest [bpm]	71.0 ± 12.4	65.4 ± 9.0	68.9 ± 11.5	-0.307*
HRr [bpm]	69.2 ± 14.6	62.8 ± 12.9	66.6 ± 14.2	-
SBP [mmHg]	114.1 ± 4.8	117.2 ± 8.9	115.3 ± 6.7	-
DBP [mmHg]	72.7 ± 4.0	73.0 ± 3.2	72.8 ± 3.7	-
PBF [%fat]	26.9 ± 7.0	13.2 ± 5.9	21.8 ± 9.3	0,010
Waist [cm]	73.6 ± 7.3	86.5 ± 6.7	78.4 ± 9.4	-0,082
BMI [kg/m^2]	23.6 ± 3.3	25.9 ± 2.4	24.4 ± 3.2	-0,107
Peak HR [bpm]	160.1 ± 17.2	148.1 ± 11.4	155.7 ± 16.3	-0,187
VO$_2$max [ml/kg/min]	39.5 ± 4.0	54.8 ± 6.3	45.1 ± 9.0	-0,187

Means ± standard deviations (SD) for mass, height, age, percent body fat [PBF], resting heart rate [HR rest], heart rate recovery [HRr], systolic and diastolic blood pressure [SBP, DBP], waist circumference [Waist], body mass index [BMI], and volume of maximal oxygen consumption [VO$_2$max], *denotes statistically significant correlation with HRr, $p<0.05$.

Resting HR showed a moderately negative correlation with HRr (r = -.307, p = .032), indicating that a person with a lower resting HR had a greater HRr (Figure 1). No other physiological measures had a statistically significant correlation with HRr.

Statistical analysis of the POMS questionnaire (Table 2) revealed participants showed the greatest disturbance with vigor. The positive mean score indicated that several participants were feeling low energy, lacking vigor at the time of testing. No other POMS variables showed significant disturbance in the patient population; and the low negative correlation with HRr indicated that mood had no significant influence on HRr.

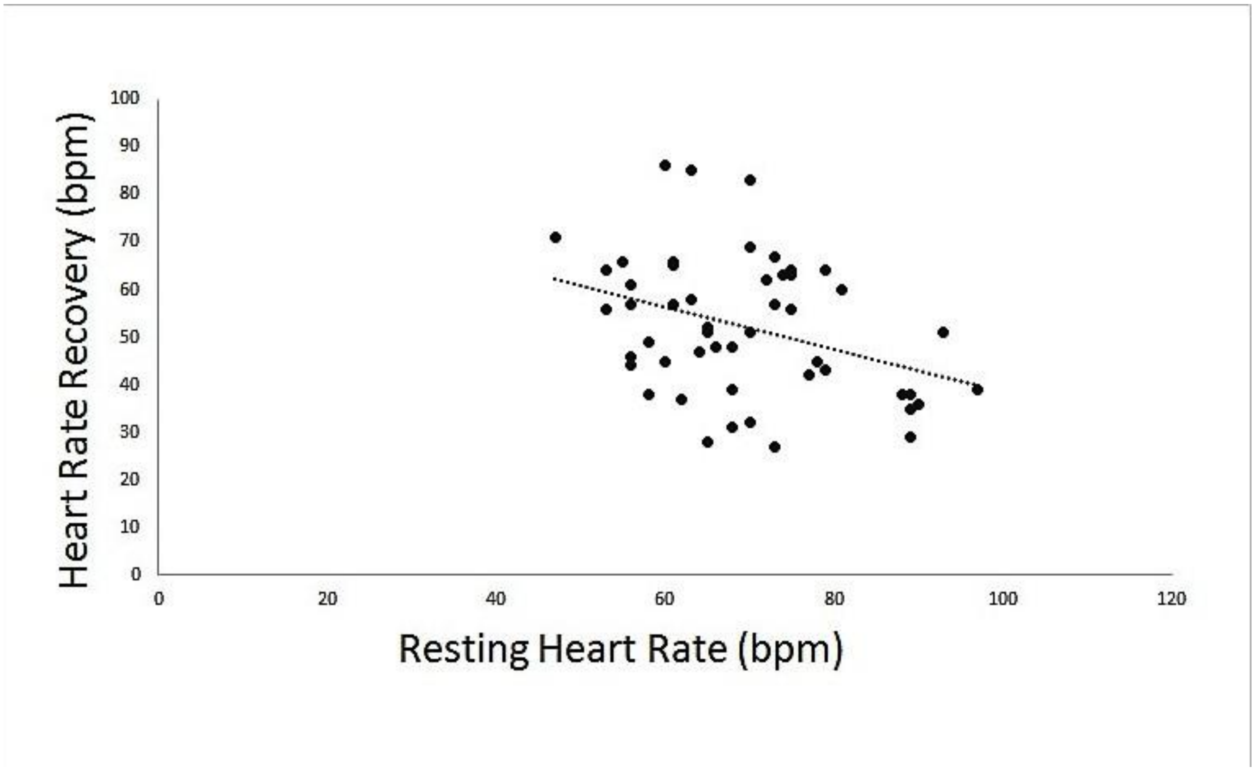

Figure 1. Correlation of resting HR and HRr (r=-0.307, p=0.032). Moderate negative correlation indicates participants with lower resting heart rate are more likely to have an enhanced HRr post-exercise

Table 2. Profile of Mood States

	Female (n=31)	Male (n=19)	Total	R-value
Anger (0-48)	0.74 ± 1.5	2.5 ± 4.4	1.4 ± 3.0	-0,192
Confusion (0-28)	3.5 ± 2.0	3.6 ± 2.7	3.6 ± 2.3	-0,203
Depression (0-60)	1.5 ± 3.2	0.78 ± 1.6	1.2 ± 2.7	-0,015
Fatigue (0-28)	3.4 ± 2.8	2.6 ± 1.9	3.1 ± 2.5	0,188
Tension (0-36)	5.3 ± 3.9	4.8 ± 3.4	5.1 ± 3.7	-0,067
Vigor (-32-0)	-13.5 ± 5.6	-15.1 ± 6.0	-14.1 ± 5.8	-0,043
TMD (-32-200)	0.61 ± 12.8	-0.94 ± 12.0	0.04 ± 12.4	-0,029

Means ± Standard Deviations (SD) for POMS subscales and total mood disturbance [TMD].
*Indicates a significant correlation with HRr, $p<0.05$.

DISCUSSION

This study was conducted to assess the relationship between fitness and mood state with HRr after completion of submaximal exercise. None of the mood factors were shown to be significant predictors of HRr, and the only physiological variable correlated with HRr was resting HR. The lack of physiological significance was unexpected, as researchers and medical professionals have long touted that good cardiovascular fitness, indicated by high VO_2max, healthy BMI, and healthy body composition, is associated with fast HRr, and therefore decrease risk of morbidity and mortality.

As high fitness levels can lead to a decrease in resting HR, the inverse relationship observed between resting HR and HRr was anticipated. This may be due to increased plasma volume, allowing for a greater stretch on the heart and increase stroke volume, or greater parasympathetic nervous system sensitivity (Barak et al., 2011; Lauer, 2011). There are several studies that found improved HRr resulting from regular exercise of subjects (Buchheit et al., 2008; Buchheit et al., 2012; Carroll et al., 2012; Simhaee et al., 2013), and others that have found significant correlations between HRr and VO_2max (Barak et al., 2011; Lee & Mendoza, 2012). Considering the majority of participants in this study were of at least average cardiovascular fitness, it is reasonable to assume that these participants had enhanced vagal tone and increased plasma volume allowing for a quicker recovery. This is supported by previous literature comparing athletes and non-athletes which demonstrated that athletes had an overall lower resting HR than the non-athletes (Barak et al., 2011). The parasympathetic nervous system is also important during exercise recovery, influencing HR to return to resting values (Buchheit & Gindre, 2006), solidifying the link between increased level of fitness and enhanced HRr.

In the present study, none of the expected predictors of HRr, including VO_2max showed any significant correlation with HRr. Previous research on this topic seems to be equivocal, with support for consistent endurance and strength training resulting in more rapid HRr (Barak et al., 2011), as well as support for no relationship between VO_2max and HRr (Buchheit & Gindre, 2006). This disagreement may be attributed to fitness level and exercise participation. Participants in the present study reported frequency and types of exercise, but did not report exercise intensity. This is a limitation of the study, as intensity may be linked with HR, rather than simply frequency and mode of exercise.

Additionally, body composition, BMI, and waist circumference showed no correlation with HRr in this study. Again research in this area is unclear, with support for a relationship between body composition and HRr (Esco et al., 2011), and indication that no association exists between BMI and HRr (Carroll et al., 2012). Despite a BMI for males in this study classifying them as overweight, waist circumference and body composition values remained low, suggesting an excess lean mass rather than fat mass. This could be a contributor to the lack of correlation between the slightly elevated BMI measurement and HRr. Another limitation of this study is that the participant population was healthy and recreationally active. It has been suggested that low levels of body fat and unvaried body composition in athletic populations can result in insignificance between body composition, BMI, and waist circumference against HRr (Lee & Mendoza, 2012).

With regard to mood states measured by the POMS survey, there was no significant correlation found when compared with HRr. Psychological stress and feelings of fatigue influence one's recovery by increasing sympathetic nervous system activity (Pronk et al., 1995; Schmikli et al., 2010), but that could not be reproduced in this study. One explanation is that the POMS subscale scores in this study were all low, indicating little mood disturbance. Participants likely did not experience a large enough change in mood to affect HRr. Future studies working with fit individuals, or measuring HRr in association with repeated measures of the POMS, may help assess the relative of impact of mood state or fitness on HRr in healthy individuals.

CONCLUSIONS

This study is novel in that it addressed both physiological and emotional influences on HRr in health individuals. While resting HR was the only significant physiological correlate, the inclusion of mood states with HR data makes this study significant because most literature assesses psychological stress after exercise rather than before. Further investigation may examine the role of mood states prior to exercise and bolster current evidence on mood states improving athletic performance (Beedie et al., 2000) or providing a physiological advantage concerning fitness (Barak et al., 2011; Lee & Mendoza, 2012).

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