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Effect of Training Mode on Post-Exercise Heart Rate Recovery of Trained Cyclists

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Abstract

Exercise causes various physiological changes to compensate for the stress on the body. During exercise the sympathetic nervous system plays a dominant role in regulating body function, but after exercise the sympathetic nervous system withdraws and the parasympathetic nervous helps the body return to a resting state. One way to observe the rate at which this happens is to measure heart rate recovery (HR_{Rec}). **PURPOSE:** The goal of this study was to compare recovery heart rates of anaerobically trained and aerobically trained cyclists. **METHODS:** Anaerobically trained track cyclists ($n=10$, age= 25.9 ± 6.0 , weight (kg)= 82.7 ± 7.1 , % body fat= 10.0 ± 6.3) and aerobically trained road cyclists ($n=15$, age= 39.9 ± 8.5 , weight (kg)= 75.3 ± 9.9 , % body fat= 13.1 ± 4.5) underwent a maximal oxygen uptake test and heart rates were recorded at 1 and 2 minutes after exercise. HR_{Rec} was calculated by $(HR_{max} - HR_{min1/2}) / (HR_{max} - HR_{resting})$ to obtain a relative change and as a simple difference between max HR at HR at minutes 1 and 2. **RESULTS:** The mean post-exercise change in heart rate at minute one was 22 ± 8 bpm for the track cyclists and 25 ± 12 bpm for the road cyclists. At minute two, the track cyclists had a mean drop of 52 ± 15 bpm and the road cyclists had a mean drop of 64 ± 11 bpm. Only the difference at minute two was statistically significant ($p = 0.028$). **CONCLUSIONS:** Training mode showed statistically significant effects on the speed of heart rate recovery in trained cyclists. Greater variability in recovery heart rate at minute two than minute one suggests that heart rate should be monitored longer than one minute of recovery for a better analysis of post-exercise autonomic shift.

INTRODUCTION

Involuntary body functions are controlled by the autonomic nervous system. The autonomic nervous system has two parts: the sympathetic nervous system which dominates when the body is stressed or excited and the parasympathetic nervous system which helps the body return to and maintain a resting state. During exercise the sympathetic nervous system controls body function, but post-exercise there is a shift in the autonomic nervous system and the parasympathetic system reactivates to return the body to a resting state (4). Part of the sympathetic effect during exercise is the raising of the heart rate via stimulation of cardiac beta-1 receptors. (-) During rest, heart rate is lowered to a resting rate via reactivation of the vagal nerve by the parasympathetic nervous system (-). The interaction between parasympathetic and sympathetic activity in regards to controlling heart rate has been studied using drugs that cause a parasympathetic or sympathetic blockade and observing the effect on heart rate (3). Such studies have shown that post-exercise decreases in heart rate are almost exclusively controlled by parasympathetic reactivation as opposed to sympathetic withdrawal (11) and have confirmed this post-exercise decrease in heart rate as both a marker of physical fitness and overall cardiovascular health (4).

There are two established, noninvasive methods of detecting sympathetic withdrawal and parasympathetic reactivation in exercising participants: measurement of heart rate recovery (HR_{Rec}) and heart rate variability (HRV). HR_{Rec} is defined as the rate at which heart rate decreases to a resting rate after cessation of moderate to heavy exercise (4). This can take from one hour to one day depending on exercise intensity and cardiovascular fitness (6). Despite a range of possible intensities and durations, a drop in heart rate less than 12 bpm in the first minute of recovery is considered abnormal and indicative of cardiovascular impairment (1). There is

currently no standard in measuring HR_{Rec} . Some studies have calculated time constants by fitting HR decay data to mathematical models (8, 10) while others look at the difference between peak heart rate and post-exercise heart rate at one to two minutes after exercise (12, 7). HRV is defined as the standard deviation of the subjects R-R intervals. High variability is indicative of cardiovascular health whereas low variability is indicative of cardiovascular impairment (3).

While a relationship between HRV and HR_{Rec} would be expected due to the fact that they both are measures of a shift in autonomic function, currently no relationship has been observed (3). This suggests that there may be more factors at work in lowering heart rate post-exercise than parasympathetic alone such as blood metabolites (e.g....) , type of previous exercise training (e.g....) and type of exercise during the assessment (i.e. anaerobic vs. aerobic). Results from Buchheit et al. (4) seem to confirm this suggestion as they found that HR_{Rec} was faster after endurance exercise trials than after repeated sprint or high intensity exercise trials performed by the same subjects. Subjects' HR_{Rec} and HRV were calculated after moderate continuous exercise, repeated sprint exercise, and high intensity intermittent exercise and they found that parasympathetic reactivation as assessed via was slower after the high intensity and repeated sprint exercise than the moderate continuous exercise. Therefore, they suggest that parasympathetic reactivation after sprint exercise is affected more heavily by stress metabolites (i.e. lactate and H⁺ concentration) and anaerobic contribution than parasympathetic reactivation after aerobic exercise. Furthermore, HRV and HR_{Rec} measure different aspects of post-exercise autonomic shift: HR_{Rec} being more indicative of vagal tone and HRV being more indicative of parasympathetic activation (3). Heffernan et al. (7) made similar observations. When testing for change in HRV and HR_{Rec} after short-term resistance training protocols they found no change in HRV, but did see change in HR_{Rec} . Both variables are valuable to athletes because they are good

markers of overall fitness and training status, including overtraining (10), however, HR_{Rec} is the most easily applicable method for athletic training as it requires no special equipment.

Results of previous studies suggest that autonomic adaptation to exercise vary depending on training mode and type of exercise performed. Multiple studies have shown that HR_{Rec} improves with training in both sedentary and already trained subjects (9, 10). Fourteen well-trained cyclists participated in a 4-week high-intensity training program and showed significant increase in HR_{Rec} at 60s after cessation of a maximal exercise test (10). It has also been observed that strength and endurance training alike improve HR_{Rec} (11). The time constant of post-exercise heart rate decay, another method of measuring vagally mediated post-exercise HR_{Rec} , was shown to be decreased in strength trained and endurance trained subjects when compared to sedentary subjects. However, the decrease in decay did not display a training specific response as no significant difference was observed between the two trained groups (11). Other similar studies have observed a similar improvement in post-exercise HR_{Rec} after resistance training and further suggest that the mechanisms of post-exercise HR_{Rec} may be slightly different in strength and endurance trained athletes (7).

The current study compared the effect of continuous training mode on the heart rate recovery of trained track (anaerobic) and road (aerobic) cyclists at one and two minutes post-exercise.

METHODS

Participants

Following Institutional Review for the Protection of Human Subjects approval at Loyola Marymount University. Ten track cyclists (1 female, 9 male) and 15 road cyclists (4 female, 11 male) were recruited to participate in the study. All participants were amateur athletes who

trained more than six hours per week in their respective training modes for at least 2 years. All subjects gave written informed consent and completed a Physical Activity Readiness Questionnaire (PAR-Q) before inclusion in this study to ensure that they were free of any injury or medical condition that may have affected performance (1).

Instrumentation

All data was collected during a one-day session comprised of resting values, maximal exercise testing, and recovery variables. Maximal oxygen testing to measure maximal oxygen consumption (VO_{2max}), maximum heart rate (HR_{Max}), and recovery heart rates (HR_{Min1} and HR_{Min2}) took place in the Human Performance Laboratory at Loyola Marymount University using an Ergonomic 894E Peak Bike (Monark). Respiratory gas exchanges were measured using Vmax Spectra 29 Metabolic Cart (SensorMedics) and calibrated for volume, flow, and gas concentrations prior to each test. A 12-lead electrocardiogram (ECG) during rest and exercise was obtained to monitor heart rate and ensure safety respectively.

TABLE 1. Selected characteristics of study participants.

| | Track ($n=11$) | Road ($n=15$) |
|--------------------------|------------------|-----------------|
| Age (yr) | 25.9 ± 6.0 | 39.9 ± 8.5 |
| Gender | 2 F, 9 M* | 4 F, 11 M |
| Weight (kg) | 82.7 ± 7.1* | 75.3 ± 9.9 |
| % Body Fat | 10.0 ± 6.3* | 13.1 ± 4.5 |
| Resting HR (bpm) | 56 ± 6.9 | 52 ± 7.9 |
| Heart Rate Reserve (bpm) | 133 ± 9.9 | 134 ± 7.8 |

Denotes statistically significant difference ($p < 0.05$). All values are reported as mean ± SD.

Maximal Oxygen Uptake Testing

After a supine resting 12-lead ECG and resting heart rate were obtained, participants were permitted to warm up as long as necessary. These athletes were highly trained so they had

established warm-up procedures in place. The average warm up time was 10 minutes. They were fitted with a respiratory valve and nose clip immediately prior to the start of the test. During the test, the subject began pedaling at a comfortable, steady cadence for these participants, rpms ranged between 75-90 throughout the test. The power was increased in 50W increments every two minutes until the end of the test and the following physiological variables were recorded: oxygen uptake, respiratory exchange ratio, heart rate (automatically, each every 10 seconds), power and rate of perceived exhaustion using a Borg scale (each every 2 minutes). The test was completed when two out of four of the following criteria were met: (a) heart rate came within 10-12 beats of age predicted maximum, (b) there was a plateau in oxygen consumption even with increased workload, (c) respiratory exchange ratio became greater than 1.05-1.15, or (d) subject requested to stop (2). Upon completion of the test protocol, resistance was reduced to pre-test wattage, subjects were allowed to pedal lightly for the first minute as recommended by the ACSM's Guidelines for Exercise Testing and Prescription (1), but were asked to sit without speaking or moving for the second minute of recovery. The cyclists' short term HR_{Rec} variables were calculated as maximum heart rate during the test minus heart rate at one minute (HR_{min1}) and two minutes (HR_{min2}). Relative change in heart rate was calculated as maximum heart rate minus HR_{min1} or HR_{min2} divided by HR_{max} minus $HR_{resting}$.

Statistical Analysis

Descriptive data are reported as mean \pm SD and t-tests were used to determine ht, wt, age, %BF, VO2max, and differences between training groups. Levene's test for homogeneity of variance were performed on all dependent variables which were found to be normal. A one-way ANOVA test was conducted to evaluate differences between a relative change in heart rate at minutes one and two (calculated as the difference between HR_{max} and recovery heart rate divided by the

difference between HR_{max} and $HR_{resting}$) and the drop in beats per minute (bpm) between max HR and recovery heart rate at minutes one and two. Statistical significance for all test was set at $p < 0.05$. Subsequent ANOVA tests determined that there was no significance difference in HR_{Rec} when grouped by gender and that maximal oxygen uptake was not significantly different between training groups. Therefore, gender data remained pooled based on training type for the analysis of the between-groups difference. There was a significant difference between the ages of participants in the groups and Pearson correlations revealed a low but statistically not significant relationship between age and HR_{Rec} ($r = 0.23$, $p = 0.26$). Statistical testing was carried out using the Statistical Package for the Social Sciences version 18.0 for Mac (PASW, Chicago, IL).

RESULTS

Testing variables including those of recovery are included in Table 2. The mean post-exercise change in heart rate at minute one was 22 ± 8 bpm for the track cyclists and 25 ± 12 bpm for the road cyclists. At minute two, the track cyclists had a mean drop of 52 ± 15 bpm and the road cyclists had a mean drop of 64 ± 11 bpm. The relative drop in HR was also greater for the road cyclists at each time point than the track cyclists (Minute 1: 19% for road, 16% for track; Minute 2: 48% for track, 40% for road). The mean drop in heart rate when calculated as a percent or a difference in beats per minute was significantly different between the two training groups at minute two ($p = 0.33$, $p = 0.028$) but not at minute one ($p = 0.488$, $p = 0.445$).

TABLE 2. Results of maximal oxygen uptake test.

| | Track (<i>n</i> =11) | Road (<i>n</i> =15) |
|---|-----------------------|----------------------|
| Peak Power (W) | 352.3 ± 48.5 | 372.7 ± 69.6 |
| Relative Peak Power (W·kg ⁻¹) | 4.4 ± 0.6 | 5.0 ± 0.7 |
| Standard VO _{2max} (mL·kg ⁻¹ ·min ⁻¹) | 54.9 ± 5.4 | 53.4 ± 7.0 |
| HR _{Rec} Minute 1 (bpm), % | 22 ± 8, 16% | 25 ± 12, 19% |
| HR _{Rec} Minute 2 (bpm), % | 53 ± 15, 40% | 64 ± 11, 48% |

Denotes statistical significance ($p < 0.05$). All values are reported as mean ± SD.

DISCUSSION

The main purpose of this study was to compare the rate of post-exercise recovery of trained track and road cyclists by measuring their recovery heart rates at one and two minutes after maximal exercise testing. The aerobically trained road cyclists showed faster HR_{Rec} than the anaerobically trained track cyclists at both one and two minutes of recovery, with a statistically significant difference between the two groups at minute two (track 40%, road 48%). These results were expected as aerobic endurance training has shown to improve other variables indicative of cardiovascular health such as left ventricular wall thickness (11) and relative maximal oxygen uptake. However, these differences in HR_{Rec} between the two groups were only significant at minute two.

This differs somewhat from the findings of previous studies. A study done by Otsuki et al. (11) also found differences in recovery heart rates of endurance and strength athletes, but these differences were not significant. However, one marked difference between the current study and that of Otsuki et al. (11) is that they used mathematical modeling to describe heart rate recovery during the first 30 seconds of recovery. They concluded that post-exercise heart rate recovery may be carried out differently in strength and endurance trained athletes. Heffernan et

al. (7) made a similar suggestion that resistance exercise seems to increase vagal tone (defined as release of acetylcholine by the vagus nerve on the heart's autorhythmic cells and increased receptor number/sensitivity) more than parasympathetic modulation. This suggests that it would be most useful to use several different variables to study the effect of training mode on overall post-exercise autonomic shift to account for specific influence of different training modes. Further studies are also needed to better define the specific implications of variables such as HR_{Rec} and HRV as individual variables may be more meaningful to specific athletic and clinical populations.

We observed that the change in HR at minute two, whether calculated as a simple difference or as a relative change, was more indicative of overall heart rate recovery ability in elite athletes than minute one. Although the difference at this time point was not statistically significant, there was greater variability between the two groups than HR at minute one. While there is no standard for measuring HR_{Rec} , this suggests that recovery HR should be monitored past minute one for a better understanding of overall autonomic shift, at least for athletic applications.

In contrast, Watanabe et al. (13) found that one minute heart rate recovery was more statistically related to all-cause mortality than two or three minute heart rate recovery when testing patients referred for stress testing. This suggests that the time points or measures of HR_{Rec} most useful for clinical applications may be different from time points or measurements useful to studies looking to measure training status or fitness.

In conclusion, as more studies examine the exact methods of post-exercise autonomic shift and the variables that describe it, it is clear that it is a very complex system. HR_{Rec} and other related variables have obvious value in both clinical and athletic applications, but more research

is needed to clearly define what part of post-exercise recovery such variables describe. In athletic applications, this would allow coaches and athletes to use these measures of post-exercise autonomic shift to better monitor specific aspects of training and recovery as it relates to their training.

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