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ISSN: 2322-4789
Asian Journal of Medical and Pharmaceutical Researches
Asian J. Med. Pharm. Res. 4 (1): 35-39, 2014

AJMPR

The Response of Blood Buffering Capacity to Three Types of Recovery during Repeated High-Intensity Endurance Training

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ABSTRACT: The aim of this study was to determine the response of chosen parameters of blood buffering capacity to three types of recovery during repeated high-intensity endurance training. Ten physical education students studying at Kharazmi University of Tehran participated in this study. They performed repeated high-intensity endurance test (RHIET) in each session. The RHIET consists of four bouts about 2:30 minutes. Recovery periods of 5minutes were allowed between bouts. RHIET differed in the kind of activity performed during the recovery periods; Gouging at 63% maximum heart rate, stretching exercises and lying down in supine position. A sample of 5CC arterial blood obtained from each individual immediately after the last recovery period. Blood sample were sent to the laboratory for homology test. Their buffering capacity was measured by assessment of the following parameters: pH, HCO3–/CO2, buffer base (BB), base excess (BE), O2-sat, PO2. The ANOVA Repeated-Measures was use to analyze the data by SPSS 17. Significant differences were shown between the active recovery and the stretching exercises recovery and between the passive recovery and the stretching exercises recovery on pH, BB and between active recovery and the passive recovery on O2-sat and PO2 ($P \leq 0/05$). There were no significant differences between the active, passive and stretching exercises recovery on HCO3–/CO2, PCO2 and IS ($p \leq 0/05$). Therefore, this study showed that the passive recovery improve buffering capacity compared to the stretching exercises and the active recovery. It could be also hypothesized that increased alveolar gas exchange with passive recovery can due to slower heart rate and slower breathing rate; the kidneys removal of H+ and HCO3- reabsorption; decreased metabolism and metabolic products, Whole body temperature (muscle, blood), and strongly oxygen binding to hemoglobin. Hence, pH will increase and buffering capacity will be improved.

Key words: Recovery, Repeated High-Intensity Endurance Training, Blood Buffering Capacity

ORIGINAL ARTICLE
Received 19 Aug. 2013
Accepted 03 Dec. 2013

INTRODUCTION

Many sport activities are known by repeated maximal or nearly maximal periods of short-duration exercises followed by recovery periods during which exercise is either continued at a much lower intensity (active recovery) or is interrupted (passive recovery). These exercises are referred to as repeated high-intensity training (HIT). There is a general belief in the training field that active recovery with light exercise or just stretching allows for better performance during the next periods of high-intensity exercise than does passive recovery. However, experimental data are not conclusive. While some researchers have reported greater exercise capacity with active recovery (Hemmings et al., 2000; Graham et al., 2003;Coffey et al., 2004; Lattier et al., 2004; McAinch et al., 2004; Hunter et al,. 2006; Spencer et al., 2006; Buchheit et al., 2009; Heyman et al., 2009), others have not confirmed these results (Bangsbo et al., 1994; Dupont et al., 2003-2004; Argyris et al., 2004;Toubekis et al., 2005; Jougla et al., 2010). Part of the contradiction may be due to differences in the duration of recovery and the intensity at which the exercise bouts were performed.

Active recovery may accelerate the removal of lactate from the active muscles and increase its utilization as a fuel source by neighboring muscle fibers. Thus, it is possible that low-intensity active recovery may decrease muscle acidosis when performed during repeated maximal or nearly maximal bouts of short-duration exercise. This process may be negatively associated with changes in blood and muscle pH (Bishop et al., 2004).

Stretching exercises could also facilitate recovery during HIT. Stretching exercises such as passive movements performed by external forces without muscle contraction (Bangsbo et al., 2000) could enhance muscle blood flow during the recovery periods by inducing shear stress, which causes the release of nitric oxide (Koller and Bagi, 2002). It is likely that the stretch and subsequent static contraction causes a short phase of muscular

To cite this paper: Fashi M., Kazemi K., Sheikhani Shahin H., Khani M. and Rostamzad K. 2014. The Response of Blood Buffering Capacity to Three Types of Recovery during Repeated High-Intensity Endurance Training. *Asian J. Med. Pharm. Res.,* 4 (1): 35-39.

ischemia (Wisnes and Kirkebo, 1976), which could induce a transient elevation of muscle blood flow at the end of the stretching exercise by eliciting post exercise hyperemia (Osada et al., 2003).

It could be also proposed that the energy required to run throughout short active recovery would result in less oxygen being available to reload myoglobin and haemoglobin, to clean off lactate concentrations and to resynthesize the phosphocreatine (Dupont et al ., 2004).

Therefore, the main aim of this study was to determine the response of blood buffering capacity to three types of recovery during repeated high-intensity endurance training.

MATERIALS AND METHODS

Subjects

Ten male students studying Physical Education at Tarbiat Moallem University of Tehran with mean age of 22.49±0.33 years, weight of 68.33±7.31 kg and height of 176.76±8.32 cm participated in this research. At the start of the study, health status of the subjects was approved by a questionnaire (rPar-Q). The subjects fulfilled a written consent form for participation in this study and all the study methods and protocols were approved in advance by the Institutional Review Board at Kharazmi Ubiversity (Grant No: 522013). During the research period, medicine and food intake of the subjects were controlled as much as possible. Temperature and humidity were 34±2.3 c ° and 36±6% respectively. The subjects were asked to preserve their physical activity at a normal level 24 hours before each test session.

Experimental Protocol

Subjects implemented three types of recovery including active recovery, passive recovery and stretching exercise recovery during repetitive high intensity endurance test (RHIET) in a period of one week (three sessions per week). Active recovery intensity was calculated and controlled during the exercise protocol based on maximum heart rate by the Karvonen and David formula. At the first week subjects were familiarized by the protocols. At the second week of the study the protocol was performed. Protocol was consisted of four bouts of physical activity and a four-bout recovery (active, passive and stretching). Each bout of physical activity was lasted two minutes and 30 seconds that included performing six times RHIET. Each subject had 30 seconds to perform this test with maximum power.

If it was completed earlier, they would rest until 30 seconds rest. Between each bout there was five minutes recovery - active (63% maximal heart rate), stretching (upper body muscles towards the leg muscles) and passive recovery (lying down) (Figure 1).

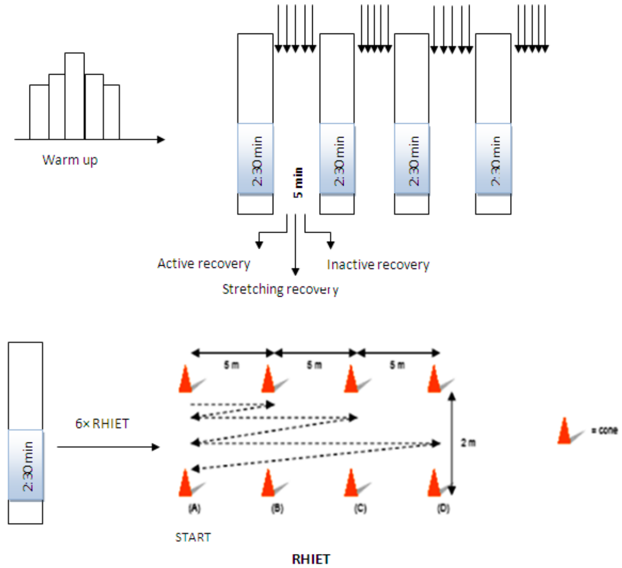

Figure 1. Layout of Repeated High-Intensity Endurance Test (RHIET) protocol

Blood Sampling

At the last stage of recovery after exercise protocol, 5cc arterial blood samples were obtained from the inner region of the wrist by an insulin syringe. To prevent blood clots and removing the effect of heparin 1 ml heparin was used in all samples. Blood samples were sent to Rajai Hospital Branch laboratory for further analysis of the blood gases. As each group had to perform all types of recovery during the study in a cross design, there was no need to match the groups.

Statistics

For statistical analysis Kolmogorov - Smirnov was used to approve normal distribution of data and then ANOVA repeated measures and LSD post hoc test under SPSS software version 17were used in the significance level of 0.05.

RESULTS

Results from the Kolmogorov-Smirnov test indicated that data for pH, HCO_3^-/CO_2, Buffer Base (BB), Base excess (BE), O_2-sat, PO_2 displayed normality of distribution. The data of pH, HCO_3^-/CO_2, BB, BE, O_2-sat, PO_2 for the three Conditions, active and passive and stretching recoveries are shown in table 1 and 2.

There was a significant difference between the active recovery and the stretching exercises recovery and between the passive recovery and the stretching exercises recovery on pH, BB and between active recovery and the passive recovery on O_2-sat and PO_2 ($P \leq 0/05$). There were no significant differences between the active, passive and stretching exercises recovery on HCO_3^-/CO_2, PCO_2 and BE ($p \leq 0/05$).

Table 1. Results of descriptive statistics (mean ± standard deviation)

Variable / Recovery group	PH	Po_2 (mmHg)	O_2-sat (mmHg)	BB (mmol/L)	BE (mmol/L)	HCO_3^-/PCO_2
Active	7.373±0.011	88.21±7.11	86.91±4.84	46.24±1.57	-1.88±1.63	0.570±3.17
Stretching	7.324±0.04	90.00±4.21	87.55±2.88	43.00±4.33	-3.92±3.96	0.533±4.81
Passive	7.378±0.014	95.11±6.18	91.31±4.46	46.56±1.32	-1.62±0.89	0.572±2.63

Table 2. Result of inferential statistic - analysis variance for repeated measures ¬ post hoc test with LSD

Variable	Unit	Dif. Between group	P value
PH	pH =(log aH $^+$)$_{10}$	Active - Stretching	0.000*
		Active- Passive	0.723
		Passive - Stretching	0.000*
Po_2	(mmHg)	Active - Stretching	0.711
		Active - Passive	0.049*
		Passive - Stretching	0.104
O_2-sat	(mmHg)	Active - Stretching	0.733
		Active - Passive	0.025*
		Passive - Stretching	0.053
BB	(mmol/L)	Active - Stretching	0.014*
		Active - Passive	0.798
		Passive - Stretching	0.008*

*Significant difference

Acidity of arterial blood (pH)

The pH indicates the hydrogen ion activity or the "effective" H^+ concentration of a solution (H^+ activity = fH· [H^+]). Repeated high intensity endurance training results in large ionic changes and an increased none-mitochondrial ATP turnover, contributing to the accumulation of hydrogen ions (H^+). Whereas recent findings indicate that the role of H^+ accumulation during the fatigue process in muscle fibers may be limited, the accumulation of H^+ has been shown to affect oxidative phosphorylation, enzyme activity, and ion regulation during some exercise tasks (i.e., repeated, intense muscle contractions). Both intra- and extracellular buffering systems act to reduce the accumulation of H^+ and therefore aid in the regulation of pH. An increased muscle buffering capacity by recovery period during repeated high intensity training may improve exercise performance by preventing a large drop in pH during repeated high intensity endurance training. In this research, despite the insignificant difference between active and passive recovery, arterial blood pH value in passive recovery was higher than the value of active recovery. The result of this study was in agreement with Siegler et al. (2006) which advised passive recovery for sustained sprinting ability during short duration repeated swimming sprints.

Bicarbonate/Carbon Dioxide (HCO_3^-/CO_2)

Carbon dioxide and bicarbonate are both involved in the most important buffering systems in the blood. It is the primary buffering system in the extracellular fluid that can buffer hydrogen ions produced by mechanisms that do not involve either bicarbonate or carbon dioxide themselves. For example, it can buffer hydrogen ion changes produced normally, during exercise and recovery. This system uses a set of linked reactions, with carbon dioxide and water on one side and bicarbonate and hydrogen ions on the other ($CO_2 + H_2O \rightarrow HCO_3^- + H^+$).

Decreased HCO_3^-/CO_2 levels in the blood will tend to lower the pH and increase H^+ ion concentration. This tends to shift the O_2-Hb-Dissociation Curve to the right and reduce the affinity of O_2 to Hemoglobin. The primary function of the HCO_3^-/CO_2 buffering system in blood is to buffer H^+ ions. However, this system is especially important because the concentrations of the two buffer components can be modified largely independent of each other: CO_2 by respiration and HCO_3^- by the liver and kidney. Although the rate of changes in HCO_3^-/CO_2 among three groups of active, passive and stretching recovery wasn't significant, but after passive recovery arterial HCO_3^-/CO_2 ratio slightly was higher than stretching and active recovery. Therefore, the buffering capacity after passive recovery was better than the active and stretching recovery.

Base Excess (BE)

Base excess is defined as the amount of strong acid that must be added to each liter of fully oxygenated blood to return the pH to 7.40 at a temperature of 37°C and a PCO_2 of 40 mmHg. Comparison of the base excess with the reference range assists in determining whether an acid/base disturbance is caused by a respiratory, metabolic, or mixed metabolic/respiratory problem. While carbon dioxide defines the respiratory component of acid-base balance, the predominant base contributing to base excess is bicarbonate. Base excess or base concentration measurable in the blood, during intense exercise tends to be reduced. Intense physical activity may indicate the presence of hydrogen ions. The hydrogen ions produced during exercise may be due to increased pulmonary ventilation, thus increased pulmonary hyperventilation, increased extracellular H^+ and base excess concentration associated with increased H^+. The type of recovery during various sports activities can effect on amounts of base excess in arterial blood. Although the rate of change in BE in three groups of active, passive and stretching recovery wasn't significant, but with passive recovery amount of arterial BE slightly was higher than the amount of BE with stretching and active recovery.

Buffers base (BB)

Component of buffering System are devoid of hydrogen ions (the anionic buffers) and contains bicarbonate, phosphate, proteins with a negative charge and hemoglobin regenerated. In normal condition all current parameters are called buffers base. The present study shows that with passive recovery value of arterial blood BB is higher. Perhaps applied exercise strategy, the recovery intensity and environmental factors are involved. There is significant difference between active and passive recovery with stretching recovery that show positive effects of active and passive recovery. Despite there isn't significant difference between active recovery and passive recovery, however with passive recovery amount of BB in arterial blood was slightly more than active recovery.

Oxygen saturation (O_2-sat)

Oxygen saturation is an indicator of the percentage of hemoglobin saturated with oxygen at the time of the measurement. Oxygen is carried in the blood attached to hemoglobin molecules. Oxygen saturation is a measure of how much oxygen the blood is carrying as a percentage of the maximum it could carry. By increasing the number of O_2 molecules, oxygen binding to hemoglobin will be higher and therefore saturation of hemoglobin with oxygen will be increased. Several factors influencing the saturation of hemoglobin with oxygen include: temperature, 2, 3-BiPhosphoGlycerate, the pressure of oxygen, pressure of carbon dioxide and pH that the role of pH is special. During intense activity production of acid will be increased and leads to oxygen detachment of hemoglobin and as a result oxygen saturation decreases. According to Results of this study, arterial blood oxygen saturation is higher with passive recovery than active and stretching recovery. Also, there was a significant difference between passive and active recovery, which indicate the desired effect of passive recovery. The result of this study disagrees with Cortis et al., (2010) that had shown the significantly higher %O2- sat of quadriceps muscle following active recovery. Perhaps the high pH with passive recovery is the reason for the high arterial O2-sat with passive recovery.

Pressure of arterial oxygen (PO_2)

Arterial and muscle blood flow increases linearly with increasing Heart output as exercise intensity and thus it increases delivery of oxygen to the active muscles. If intensity of exercise increases over the optimal intensity, heart rate will consequently increase and time to receive oxygen from pulmonary will be decreased, therefore, pulmonary arterial blood oxygen pressure will fall. The results of this study indicate that arterial pressure of oxygen with passive recovery is more than active and stretching recovery. However, there is no significant difference between active and passive recovery with stretching recovery, but mean arterial pressure of oxygen with stretching recovery is more than active recovery. DuPont et al., (2003) have showed a similar trend over the same period for PO_2 after passive recovery. It could be also hypothesized that the energy required to run during short active recovery would result in less oxygen being available to reload myoglobin and hemoglobin, to remove lactate concentrations and to resynthesize the phosphocreatine. Perhaps high intensity training protocol leads to arterial blood hypoxia and with passive recovery which heart rate approach to rest, arterial blood will receive more oxygen from lunges (as a result of enough time for receiving oxygen) therefore pressure of arterial oxygen was higher with passive recovery.

DISCUSSION

The results of the present study suggest that in comparison to the stretching exercises and the active recovery, the passive recovery improve buffering capacity. This finding is in agreement with the findings of Argyris et al. (2004); DuPont et al. (2004); Siegler et al. (2006); Toubekis et al. (2007); Jougla et al. (2010) that advised passive recovery and in disagrees with researches done by Hemmings et al. (2000); Graham et al. (2003); Coffey et al. (2004); Lattier et al. (2004); McAinch et al. (2004); Hunter et al. (2006); Spencer et al. (2006); Buchheit et al . (2009) and Heyman et al. (2009) that advised active recovery. It could be also hypothesized that increased alveolar gas exchange with passive recovery can due to slower heart rate and slower breathing rate; the kidneys removal of H+ and HCO3- reabsorption; decreased metabolism and metabolic products, Whole body temperature (muscle, blood), and strong oxygen-hemoglobin binding. Hence, pH will increase and buffering capacity will be improved.

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