Pol. J. Sport Tourism 2011, 18, 105-111
DOI: 10.2478/v10197-011-0008-4

Original research papers

EFFECT OF DIFFERENT TYPES OF RECOVERY ON BLOOD LACTATE REMOVAL AFTER MAXIMUM EXERCISE

Types of recovery on blood lactate

JACIELLE CAROLINA FERREIRA[1], RODRIGO GUSTAVO DA SILVA CARVALHO[1], THIAGO MOREIRA BARROSO[1], LESZEK ANTONI SZMUCHROWSKI[1], DARIUSZ ŚLEDZIEWSKI[2]

[1] *Federal University of Minas Gerais – Brazil, Load Evaluation Laboratory*
[2] *The Josef Pilsudski University of Physical Education in Warsaw*

Mailing address: Leszek Antoni Szmuchrowski, Federal University of Minas Gerais,
Av. Antônio Carlos 6627, Pampulha, CEP 31270-901 Belo Horizonte – MG,
tel.: +55 31 91926305, fax: +55 31 34092325, e-mail: leszek_br@yahoo.com.br

Abstract

Introduction. Despite physiological changes caused by immersion in liquid medium, few studies have been conducted to determine the kinetics of blood lactate removal under these conditions. The aim of this study was to verify the effect of active recovery, using a specific water bike, on the blood lactate concentration after maximum intensity exercise. ***Material and method***. Ten healthy cycling athletes performed an Anaerobic Threshold Test by Heart Rate (HR) on a bicycle ergometer and an Anaerobic Threshold Test by Subjective Effort Perception on an aquatic bicycle ergometer. Three maximal test was performed immediately before each recovery type, in three different days: Passive Recovery on Land – PRL (horizontal position for 60 minutes), Passive Recovery in the Water – PRW (horizontal position, with the help of floats, in swimming pool for 60 minutes) and Active Recovery in the Water – ARW (the volunteer performed exercises on a water bicycle to an intensity corresponding to 85% of the intensity of LA in water, for 30 minutes, and remained in the same position of the PRW for another 30 minutes). Blood samples were collected 5, 15, 30 and 60 minutes after the maximal test, for lactate analysis. ***Results***. The [La] blood did not show the difference between the three types of recovery at 5th min. From 15th min on, the difference between the ARW and the other two types of passive recovery was significant, and the ARW showed lower values. There was no significant difference between the PRW and PRL. ***Conclusion***. Mere immersion in water is not enough to maximize the removal of blood lactate. This study demonstrates that active recovery held in water is effective for the removal of blood lactate in cyclists.

Key words: water exercise, active recovery, anaerobic threshold

Introduction

Lactate is produced in skeletal muscle for two reasons: firstly, because the acceleration of glycolysis at the onset of muscle activity is fast compared with the acceleration of the oxidative pathway, and secondly, because the maximal glycolytic capacity exceeds the maximal oxidative capacity [1]. Therefore, in high intensity exercise, the concentration of lactate is also high due to an increase in its production through the energy supply pathway and a decrease in the blood flow to tissues, which is responsible for removal of excessive lactate. Lactate concentration in muscle can be greater than 100 mmol per kilogram of dry matter during intense exercise lasting 30 seconds or more [2].

However, more than 99% of lactic acid dissociate into lactate anions and protons (H^+) at physiological pH [3]. Both ions are considered possible reasons for fatigue and consequently performance reduction when they exist in high concentrations in the body [4]. According to Gladden [3], most researchers have argued that any detrimental effect of lactic acid on muscle and exercise performance is due to H^+ rather than lactate, even though Lamb et al. [5] postulated that the lactate ion in itself reduces muscle force.

Despite the controversy regarding the effect of lactic acid and both ions in the process of fatigue [5], there are strong evidences that such metabolite resulting from anaerobic glycolysis negatively affects physical performance, mainly due to an increase in H^+ concentration. Moreover, studies in which active recovery was successfully used as a strategy to extend exercise time until exhaustion [6], or to improve performance subsequent to maximum effort, presented lower concentrations of plasmatic lactate compared to other recovery types. Therefore, blood lactate concentration can be used as an indicator of performance during intense events and those of short duration. Such evidences show that lactate removal after intense exercise is important to resume subsequent exercise, particularly during competitions, thus contributing to the achievement of intermittent and successive exercises without performance loss [7, 8].

In studies that were carried out with the aim of determining the effects of different types of recovery exercises after exhaustive effort on blood lactate removal [7, 8, 9, 10], results show that active recovery carried out in low intensity is more effective when compared with exercise recovery carried out in moderate intensity or passively. In general, the procedures used during active recovery vary according to the intensity of the activity, the type of exercise and the time of activity [8, 11, 12]. Dodd et al. [8] suggest activities with intensities close to 30 to 40% of individual $VO_{2máx.}$ Belcastro and Bonen [7] found significant results for lactate removal in intensities between 29,7 and 45,3% of the maximal oxygen uptake.

With respect to the time of exercise, values between 15 seconds and 30 minutes were tested, given the fact that better results were achieved in longer duration tests [6, 13].

Immersing the individual in water as a recovery strategy after intermittent exercise is mentioned in different studies [14, 15, 16]. Hydrostatic pressure from water immersion causes body fluids to flow up and inwardly. This reduces edema, increases the transference of extra-cellular fluids to the vascular system, and increases cardiac output. Greater cardiac output increases the blood flow and, due arterial pressure, vasodilatation may occur. The increase in blood flow helps the metabolic processing of waste accumulated during the exercise due to the reduction in time of transport. Wilcock et al. [15] affirm that only immersion in water leads to moderate improvement in the recovery of muscle strength and performance in sprints, when compared with other recovery strategies that do not use water. According to Takahashi et al. [16], exercising in the water has a massage effect depending on the resistance exerted by the liquid medium, and can be an effective method of recovery of delayed muscle pain. Despite these physiological changes caused by immersion in liquid medium, few studies have been conducted to determine the kinetics of blood lactate removal under these conditions. Therefore, the aim of this study was to verify the effect of active recovery, using a specific water bike, on the blood lactate concentration after maximum intensity exercise.

Material and methods

Ten individuals, healthy cycling athletes, took part in this study as volunteers. Each volunteer attended the laboratory for six days. First they were informed about the research aims and procedures and signed a consent agreeing to their participation in the search. This study was approved by the Committee on Ethics in Research of the Federal University of Minas Gerais and all the procedures were according to the Helsinki Declaration of 1975.

Table 1. Data on the characterization of the sample (±SD)

	Age (years)	Body Mass (kg)	Height (cm)
Mean (±SD)	26.2 (±5.55)	74.58 (±8.17)	178.89 (±8.85)

Protocol testing

On the second day the volunteers performed Anaerobic Threshold Test by Heart Rate (HR) on a bicycle ergometer [17] to determine the HR corresponding to the anaerobic threshold (AT) on bicycle ergometer (Maxx, Monark standard) on land. Data from HR were recorded from Heart Rate monitor Polar, model Xtrainer and transferred to the computer to be analyzed by the HR Analysis Software.

The following day, an Anaerobic Threshold Test by Subjective Effort Perception on an aquatic bicycle ergometer [18, 19] was performed in the swimming pool of the School of Physical Education, Physiotherapy and Occupational Therapy at the Federal University of Minas Gerais, whose water temperature is set between 28 and 32°C. An aquatic bicycle (Water Bike®) and a Heart Rate Monitor Polar®, model Xtrainer were used. This test shows the intensity of effort (RPM-Revolutions per minute and HR) corresponding to AT and allowed the control of recovery exercise intensity in the water.

Experimental procedure

Maximal Test: Volunteers performed a Wingate Anaerobic Test (WAT) of the lower limbs with a load corresponding to 7.5% of their body weight for 30 seconds [20], followed by another four 10 second maximum stimuli on the same bicycle, with the same load, interspersed by 15 seconds of rest, sitting on the bicycle. The test was performed on a Maxx® (Monark® standard) bicycle, which was connected to the Software MCE® to record and analyze the data. After testing most volunteers, they were immediately subjected to a different procedure recovery each day, determined randomly.

– Passive Recovery on Land (PRL): the volunteer remained on a horizontal position for 60 minutes in a thermoneutral room.
– Passive Recovery in the Water (PRW): the volunteer remained in the swimming pool (temperature between 28 and 32°C) on a horizontal position, with the help of floats, for 60 minutes.
– Active Recovery in the Water (ARW): three minutes after the completion of the maximal effort, the volunteer performed exercises on a water bicycle to an intensity corresponding to 85% of the intensity of LA in water, for 30 minutes, with the water temperature between 28 and 32°C, and remained in the same position of the PRW for another 30 minutes.

Both the protocol of tests and the experimental procedure were performed in the same period of the day so as to prevent possible circadian variations in performance [21].

Blood sample

During recovery procedures, blood samples were collected through puncture in the distal phalange of the right index finger of volunteers, maintaining the same pattern throughout the experiment. The samples were taken 5, 15, 30 and 60 minutes after the test.

The HR was recorded during the four moments of blood sample collection. For the determination of the blood lactate concentration ([La]), blood samples were analyzed in a lactimeter Accusport®. The data of HR were obtained from Heart Rate monitor Polar® model Xtrainer.

Statistical analysis

The variables analyzed were heart rate, blood lactate concentration and maximum power and average parameters, total work and fatigue index provided by the WAT, as well as four consecutive stimuli in the three different types of recovery. For the determination of normalcy the Kolmogorov-Smirnov test was used. Descriptive analysis was completed using a repeated measure ANOVA (SPSS version 12.0 for Windows, SPSS, Inc., Chicago, IL, USA) and a post hoc analysis of Tukey to determine possible differences between groups. The index of significance used was 5%. During the analysis of the data, the evaluator was kept blind.

Results

All parameters examined passed the test of statistical normality. The test results from the anaerobic threshold tests are presented in Table 2.

Table 2. Mean (±SD) of parameters supplied by two anaerobic threshold tests (on land and in water immersion)

Parameter	Anaerobic threshold – land		Anaerobic threshold – water	
	HR (bpm)	% HR Max	HR (bpm)	RPM
Mean (±SD)	179 (±5.66)	94 (±1.64)	146 (±14.34)	62 (±3.79)

A descriptive analysis of the data from maximum tests is presented in Table 3. Statistical analysis showed no significant difference between the parameters for relative maximum power (rMP) and total work (TW) in the three different moments of blood sample collection. These results ensure that the performances of volunteers involved the same amount of effort during the maximum tests on the three occasions.

Table 3. Mean (±SD) of parameters obtained during maximum tests before recovery procedures

Parameter	ARW	PRW	PRL
Effort 1 - 30 seconds			
rMP (W/kg)	12.086 (±0.965)	12.252 (±0.871)	12.415 (±0.657)
TW (kJ)	21.704(±3.225)	21.744 (±3.026)	22.102 (±3.121)
Effort 2 - 10 seconds			
rMP (W/kg)	8.901 (±0.600)	9.033 (±0.615)	8.848 (±0.834)
TW (kJ)	5.979 (±0.922)	6.135 (±0.918)	5.969 (±0.892)
Effort 3 - 10 seconds			
rMP (W/kg)	8.831 (±0.676)	8.918 (±0.677)	9.040 (±1.039)
TW (kJ)	5.837 (±0.801)	6.068 (±0.884)	6.070 (±1.054)
Effort 4 - 10 seconds			
rMP (W/kg)	8.983 (±1.001)	9.028 (±0.696)	8.886 (±1.041)
TW (kJ)	6.011 (±0.812)	6.008 (±0.878)	6.042 (±0.972)
Effort 5 - 10 seconds			
rMP (W/kg)	8.986 (±0.947)	8.416 (±2.451)	9.066 (±1.195)
TW (kJ)	5.997 (±0.829)	6.119 (±0.859)	6.031 (±0.952)

PRL – Passive Recovery on Land; PRW – Passive Recovery in the Water; ARW – Active Recovery in the Water; rMP – relative maximum power; TW – total work

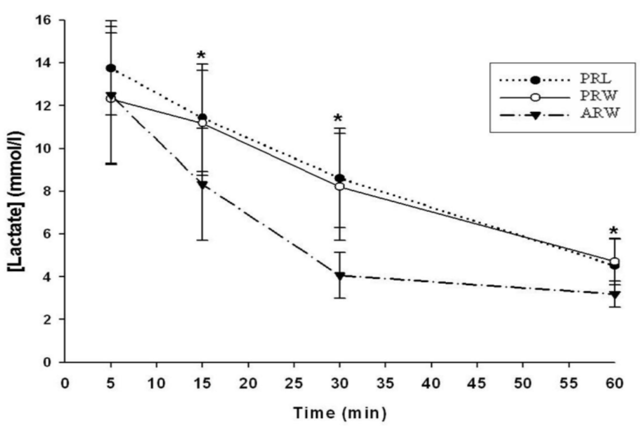
The results of the parameters analyzed during the recovery, [La] blood and HR, are presented in Table 4. The first three values of HR (5th, 15th and 30th minutes) were similar in the PRW and PRL. However, there was difference between the HR during the ARW and other types of recovery. However, the last value of HR (60th min) was the same in all three types of recovery.

Table 4. Mean (±SD) of [La] blood and HR during the different types of recovery

	ARW		PRW		PRL	
	HR (bpm)	[La] (mmol/l)	HR (bpm)	[La] (mmol/l)	HR (bpm)	[La] (mmol/l)
Minute 5	126.6* (±12.97)	12.5 (±3.19)	105.4 (±10.76)	12.32 (±3.07)	103.4 (±10.69)	13.76 (±2.205)
Minute 15	123.2* (±11.77)	8.29* (±2.57)	99.1 (±7.06)	11.18 (±2.46)	95.7 (±11.29)	11.42 (±2.507)
Minute 30	123.3* (±13.80)	4.06* (±1.07)	85.8 (±12.23)	8.21 (±2.49)	85.3 (±10.49)	8.61 (±2.324)
Minute 60	72.9 (±14.03)	3.19* (±0.62)	72.6 (±13.65)	4.71 (±1.08)	76.1 (±8.32)	4.52 (±1.230)

* – significant difference between the ARW and the other two types of recovery (PRW and PRL) in the same period of time ($p<0.05$); PRL – Passive Recovery on Land; PRW – Passive Recovery in the Water; ARW – Active Recovery in the Water

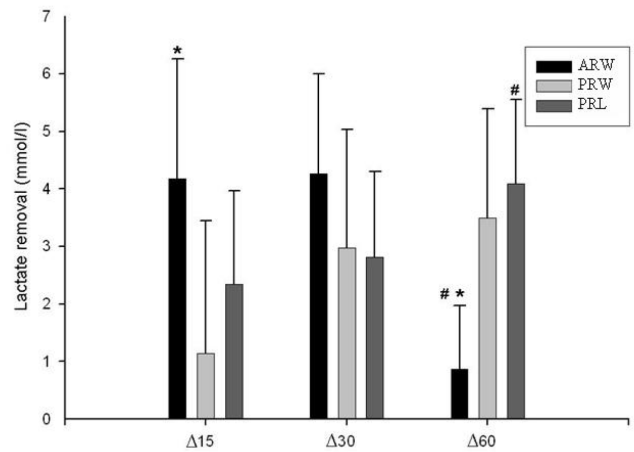
The [La] blood did not show the difference between the three types of recovery at 5th min. However, from 15th min on, the difference between the ARW and the other two types of passive recovery was significant, and the ARW showed lower values. There was no significant difference between the PRW and PRL in any of the variables examined. Figure 1 shows the kinetics of removal of blood lactate during recovery.



The values are represented as mean (±SD); * – significant differences between the group RAA compared with RPA and RPS, $p<0.05$; PRL – Passive Recovery on Land; PRW – Passive Recovery in the Water; ARW – Active Recovery in the Water

Figure 1. Graph representing the kinetics of blood lactate removal of the ARW, PRW and PRL

Figures 2 and 3 show the absolute results of the difference in the concentration of lactate (Δ) and the rate of lactate removal during different moments of blood sample collection. The values of "Δ" represent the amount of lactate removed during the interval between the blood samples. The rate of removal (RR) represents the percentage of lactate removed in the third and the fourth pick in relation to the value found at 5th min.

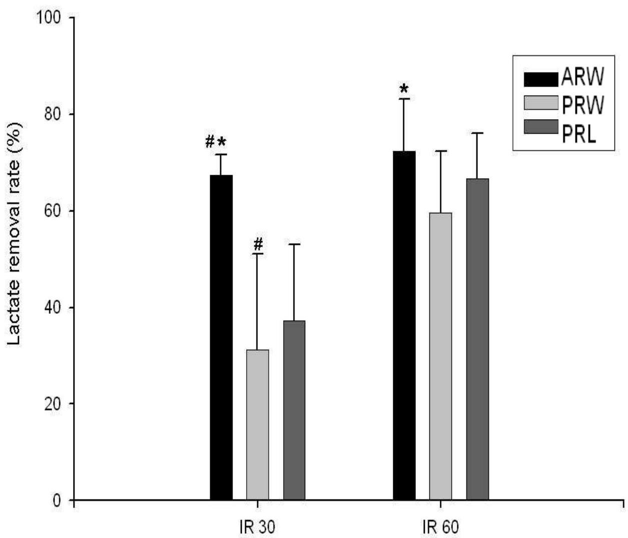


Δ 15 – amount of lactate removed between the 5th and the 15th minute; Δ 30 – amount of lactate removed between the 15th and the 30th minute; Δ 60 – amount of lactate removed between the 30th and the 60th minute; * – significant difference between ARW and PRW; # – significant difference between ARW and PRL, $p<0.05$; PRL – Passive Recovery on Land; PRW – Passive Recovery in the Water; ARW – Active Recovery in the Water

Figure 2. Graph representing the amount of lactate removed from the ranges of blood sample collections for the three different types of recovery (ARW, PRW and PRL)

The Δ15 of ARW (4.18 mmol/L) was significantly greater than that of the PRW (1.14 mmol/L) ($p = 0.006$), but was not different in the ARW and PRL and in PRW and PRL. There was no significant difference between the three different types of recovery for the Δ30. However, the Δ60 of ARW (0.87 mmol/L) was significantly smaller than that of the PRW (3.50 mmol/L) ($p = 0.002$) and the PRL (4.09 mmol/L) ($p < 0.001$). There was no significant difference between the Δ60 the PRW and the PRL.

The ARW (67.38%) was greater than the PRW (31.19%) ($p < 0.001$) and the PRL (37.24%) ($p < 0.001$) in Index of Recovery at 30 minutes (IR30) and the PRW was not different from the ARL. The Index of Recovery at 60 minutes (IR60) of ARW (72.42%) was significantly greater than that of the PRW (59.57%, $p = 0.038$). However, these values were not different in the PRL (66.68%). The IR60 of PRL was also not different from IR60 of PRW.



The values are expressed as percentile; * – significant difference between ARW and PRW; # – significant difference between ARW and PRL, $p < 0.05$; PRL – Passive Recovery on Land; PRW – Passive Recovery in the Water; ARW – Active Recovery in the Water; IR30 – Index of Recovery at 30 minutes; IR60 – Index of Recovery at 60 minutes

Figure 3. Graph representing the rate of lactate removal in the 30th min (IR30) and 60th min (IR60) after maximum exercise

Discussion

Much has been discussed about the therapeutic properties of water and the physiological changes that occur as a result of immersion in a liquid medium. However, the results presented in this study demonstrate that immersion in water, following the performance of maximal exercises, by itself does not affect the speed of blood lactate removal if the individual remains at rest, in a comparison with the same scenario on land. A different effect could be expected considering that the increase in blood flow under immersion can help in the metabolism of waste accumulated during the exercise [15]. Moreover, more blood carrying lactate could reach the visceral region, considered an important site of lactate removal [10], as the venous return is facilitated in such conditions.

Gisolfi et al. [9] claim that the increase in the rate of lactate removal in recovery exercises is probably due to the following factors: 1) faster distribution of lactate to the liver for conversion into oxidation or glycogen, 2) increased use of the lactate by the heart muscle, and 3) possible increased oxidation of lactate used as fuel for muscle work. Therefore, the completion of 30 minutes of exercises after maximal effort contributes to the reduction of the oxygen debt. In addition, this study was concerned with proposing a recovery activity similar to maximum exercise, since Stamford et al. [10] have shown that exercises conducted by muscles not fatigued and hiperoxia during the recovery are not advantageous situations, and that exercises including more muscle groups are more effective than those involving fewer muscle groups.

The intensity proposal by Belcastro and Bonen [7] as most efficient for the removal of blood lactate is that between 29.7 and 45.3% of the maximal oxygen uptake. However, two individuals with similar maximum oxygen consumption may exercise in the same relative rate but have different concentrations of lactate [8]. This difference is probably explained by different values of anaerobic threshold, hence the importance of controlling the intensity of recovery through the anaerobic threshold of the individual instead of the use of maximal oxygen uptake, as has been proposed in this study.

The strategy of using exercise to recover from the immersion in liquid proved to be effective for the removal of blood lactate, although Di Masi et al. [22] have found similar values of removal in and out of the water. However, these authors did not consider possible changes caused by immersion for the physiological variables related to the intensity of the exercise [15]. In the water, increasing the speed of pedaling can be represented by an exponential function. So, small decreases in the rate of pedaling may lead to significant decreases in the intensity of the exercise. Thus, 85% of threshold rpm controlled by the HR of anaerobic threshold in water may represent an effort to lower the intensity of real value of anaerobic threshold. However, this study did not intend to verify this fact; it can be evaluated by the record consumption of oxygen during activity.

During the experiment, the volunteers performed 30 minutes of activity after the maximum effort. According to the results, this amount of activity was sufficient for the removal of 67.38% of the lactate produced. The use of shorter amounts of active recovery may be less effective for the removal of lactate [23] or even contribute negatively to the attainment of maximum exercises [12]. Even after sixty minutes, the values of the IR in PRW (59.57%) and in PRL (66.68%) did not reach the value of ARW after thirty minutes of exercise.

Reilly et al. [24], compared passive recovery and in treadmill with the implementation of deep-water running after plyometric training. After five days of recovery, the implementation of the activity in the water has been shown to be more beneficial than the other types of recovery with higher production of power, less sense of pain and minor amounts of creatine kinase. Based on these statements, as well as on the results obtained in this study, it is possible to say that recovery in the active liquid is beneficial with regard to the recovery of both acute on chronic effects of the exercise, thus making it an interesting alternative to athletes from different sports after the strenuous effort of training or competition.

The performance of exercises after an effort that causes accumulation of blood lactate again proved to be beneficial for the removal of this metabolite of blood. The effectiveness of this type of activity is already known. Different strategies to optimize the removal of lactate have been studied. This study presents a new possibility for the conduct of activities in the water, without the need to compare this method with activities in land.

Conclusion

Mere immersion in water is not enough to maximize the removal of blood lactate. Active recovery has been more efficient than the passive kind, and its intensity can be more accurate to use the anaerobic threshold than the use of maximal parameters, such as the consumption of oxygen. The completion of 30 minutes of exercise to 85% of the anaerobic threshold is effective for the removal of approximately 70% of the lactate produced during maximal exercise.

This study demonstrates that active recovery held in water is effective for the removal of blood lactate in cyclists. The mechanisms that explain this fact are well substantiated in the literature. However, more studies are needed to demonstrate the possible benefits of the implementation of recovery in the water and the reasons why these possible benefits may be associated with an increase in performance. For future researches, we recommended a comparison between active recovery on land and active recovery in the water.

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Submitted: October 6, 2010
Accepted: February 15, 2011