

Lactic acid recovery profiles following exhaustive arm exercise on a canoeing ergometer

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In this study lactate removal rates were monitored in ten subjects during a 30-min recovery period following exhaustive arm exercise. Each subject experienced three recovery regimens on different occasions in random order. One recovery period consisted of supine rest while the other two were active, one incorporating low intensity arm exercise and the other consisting of low intensity leg exercise. Lactate clearance rates showed a significant difference between the recovery regimens, and a posteriori test indicated a significant difference between leg exercise and arm exercise in the recovery period and also between leg exercise and rest. There was no significant difference in lactate clearance between arm exercise and rest in the recovery period.

Keywords: Slalom canoeing, lactate removal, arm exercise

In the sport of slalom canoeing a competitor must manoeuvre his kayak through a series of 'gates' suspended over rapid and agitated water. The objective is to reach the finish in the shortest possible time and to avoid any time penalties which are incurred if he contacts a 'gate'. Recent developments in the sport have shortened the courses and reduced individual run times to under 2 min and as a result it might be suggested that the relative contribution of aerobic and anaerobic glycolysis has also been modified from that required for previously longer events. In a world class event when courses were longer than is suggested here, it has been shown that anaerobic involvement as manifested by post-competition serum lactate values (16.2 mmol l^{-1}) was considerable¹.

The removal of lactic acid after exercise may be important during athletic competitions since lactic acid has been shown to inhibit the rate of glycolysis². However, in slalom canoeing, where a competitor is entitled to two runs down the course, the interval between runs is often several hours and it might be expected that lactic acid levels would reach resting levels between runs³. Perhaps the rate of lactate clearance is more important for the canoeist during

training bouts where regimens are often intense and long lasting.

Many investigators have shown that the rate of lactic acid removal occurs more rapidly during aerobic recovery exercise than at rest⁴⁻⁶. Moreover, after a running bout it has been demonstrated that the intensity of recovery exercise is related to the rate of lactic acid removal. Continuous recovery exercise was shown to be more effective in removing lactate than intermittent recovery exercise³. A similar relationship between lactate removal and intensity of recovery exercise was demonstrated more recently in the sport of rowing where it was shown that during the recovery period when athletes continued rowing at 40% of maximum speed there was a greater rate of lactate removal than when recovering using a 60% speed⁷. In these studies the mode of exercise during recovery incorporated the same muscle groups as those used during lactate accumulation. Although some lactate which has accumulated from intense exercise may be removed by various organs such as the brain, myocardium, renal medulla and liver, the majority is removed by skeletal muscle⁷.

In the sport of slalom canoeing, upper body musculature is involved in intense isotonic activity while the lower body is involved in isometric synergic activity⁸. Following an event it is not always convenient for the competitor to remain in his kayak and promote lactate clearance through continued but less intense paddling activity. It would be very useful for canoeing coaches to be able to influence the rate of lactate clearance in their athletes using activity other than canoeing.

The purpose of this study was to compare the rates of lactate clearance during different modes of recovery exercise.

Methods

Subjects

Ten healthy male university students who had no experience of competitive canoeing participated in the study. Their mean (s.d.) characteristics were: age 22.0(3.9) years; weight 70.3(5.6) kg; and height 170.6(5.6) cm.

All subjects became accustomed to working on an electronically controlled (LODE) canoeing ergometer⁸. Before exercise the dominant hand of each

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subject was gently warmed by immersion in warm water for 3–4 min. The hand was dried and the subject worked on the ergometer against an initial resistance of 50 W at a rate of 60–70 revs per min, with an increment of 40 W every 2 min until volitional exhaustion.

Each subject was assigned randomly to one of three recovery protocols and each subject experienced all recovery protocols following exercise on subsequent occasions. A minimum period between exercise bouts for each subject was 48 h.

Recovery protocols

Each recovery period lasted for 30 min during which blood samples were taken from a finger tip of the dominant hand and assayed for lactate content.

Three modes of recovery were used:

1. Passive recovery where the subject rested in a supine position with a minimum of movement.
2. Active leg recovery where subjects pedalled a cycle ergometer for 30 min against a resistance of 1.5 kg at a steady rate of 30 revs per min.
3. Active arm recovery where the subject worked on the arm ergometer against a resistance of 40 W at 40 revs per min. Work intervals of 2.5 min were interspersed with rest periods of 2.5 min for the duration of the recovery period.

Lactate sampling

An Analox GM7 analyser using lysing capillary tubes containing heparin, fluoride and nitrite (Analox Instruments, Hammersmith, London) was used to determine lactate concentrations.

After exercise to volitional exhaustion, blood samples were taken at 0.5, 2 and 5 min and then at each 5-min interval for the recovery period. Mean results of subject lactate concentrations at each sampling point over three modes of recovery exercise were treated statistically using a repeated measures two-way analysis of variance (ANOVA).

Results

Mean(s.d.) blood lactate values were calculated and since these were quite variable throughout all three recovery regimens, concentrations in each recovery regimen were also expressed relative to the maximum mean lactate value recorded (Table 1). These data are illustrated in Figure 1.

It is interesting to note from Table 1 that the time at which peak mean lactate values were recorded was the same for the arm exercises and resting recovery regimens, i.e. 5 min after exhaustive exercise, but during the leg exercise recovery period peak mean lactate was recorded at 2 min. From the same table it can be seen that there was also a similarity in the peak values of lactate recorded between the resting condition and the arm recovery regimen, 11.9 mmol l⁻¹ and 11.6 mmol l⁻¹ respectively. The peak mean value recorded during leg exercise recovery was lower at 9.9 mmol l⁻¹.

After 30 min of recovery, mean lactate values for both the resting and arm exercises (5.6 mmol l⁻¹, and 4.3 mmol l⁻¹ respectively, Table 1; 47% and 37.1%

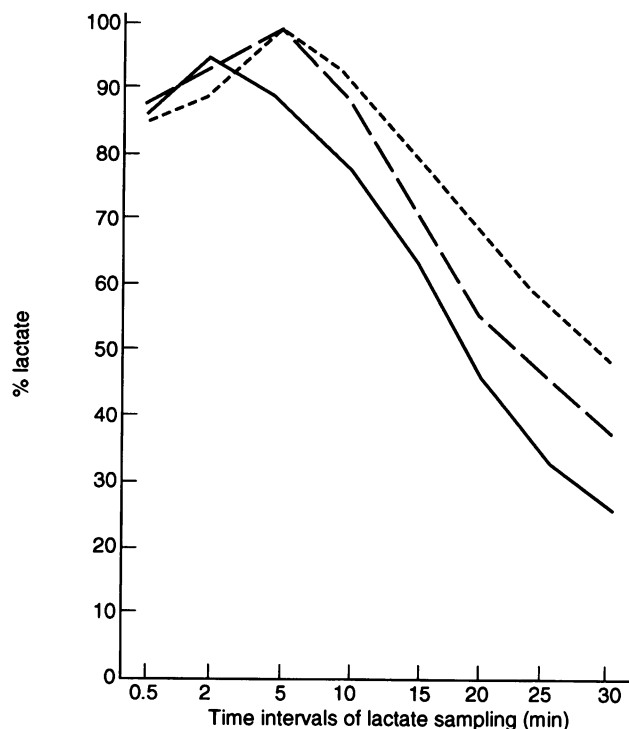


Figure 1. Lactate profiles of three recovery regimens: rest, arms and legs recorded over 30 min. Results are expressed as a percentage of mean maximum lactate values (mmol l⁻¹) for each condition: -----, rest; — — —, arms; —, legs

respectively, Figure 1) were above 4 mmol l⁻¹, which is widely used as the point at which lactate production exceeds lactate clearance rates, whereas after 30 min of gentle leg exercise approximately 75% of lactate had been removed and lactate values were approaching normal resting levels, 2.5 mmol l⁻¹.

An analysis of these results, when treated by a two-way ANOVA, revealed that there was a significant difference between recovery conditions (Table 2).

A *post hoc* Tukey test was used to determine which group means differed from each other. There was a significant difference between leg exercise and rest recovery protocols ($P < 0.01$) and a significant

Table 1. Mean(s.d.) lactate values of ten subjects during three modes of recovery, rest, leg exercises and arm exercises, over a 30-min recovery period. Values in mmol l⁻¹, and per cent lactate values shown in bold type (mean/max)

Mode	Recovery period (min)							
	0.5	2	5	10	15	20	25	30
Rest								
mean	10.3	10.9	11.9	11.1	9.5	8.0	6.7	5.6
s.d.	2.7	2.7	2.0	2.3	2.5	2.5	2.3	1.6
Per cent	86.6	91.6	100	92.3	79.8	67.2	56.3	47.0
Leg exercises								
mean	8.7	9.9	9.7	8.2	6.5	4.6	3.4	2.5
s.d.	1.7	1.7	1.6	1.3	1.2	1.1	1.0	0.7
Per cent	87.8	100	98.0	82.8	65.7	46.5	34.3	25.3
Arm exercises								
mean	10.0	10.6	11.6	10.7	8.2	6.4	5.4	4.3
s.d.	1.8	1.9	1.6	1.9	2.1	1.4	1.0	0.8
Per cent	86.2	91.4	100	92.2	70.7	55.2	46.6	37.1

Table 2. Analysis of variance results for lactate values from ten subjects sampled at eight intervals over 30 min under three independent recovery conditions

	SS	d.f.	MS	F
Between interval	144	7		
Within intervals	30.5	16		
Between conditions	27.3	2	13.63	61.9*
Residual	3.1	14	0.22	

$F_{.99}(2,14) = 6.51$

d.f., degrees of freedom

difference between leg and arm exercises ($P < 0.05$) but there was no significant difference between rest and the arm recovery protocols.

Discussion

The accumulation of lactic acid in muscle during strenuous exercise may have a significant effect on the development of fatigue⁹ and also on the quality of resumed exercise especially during athletic competition³. It is well documented that the removal of lactate following exercise is enhanced if, during recovery, the subject exercises at a reduced intensity^{6,7,10}. Although lactate can serve as a substrate for the kidney and heart muscle and is resynthesized back to glycogen in the liver, it can also be utilized by resting and exercising skeletal muscle^{9,11}.

Several studies have investigated the effectiveness of various work intensities during the recovery period on lactate clearance and it was shown that an optimum level of exercise intensity was approximately 40% $\dot{V}O_{2,max}$ ^{4,6}. Other workers have demonstrated that recovery exercise above the onset of blood lactate accumulation (OBLA), which, when expressed as a heart rate relative to maximum heart rate, is less effective in clearing lactate⁷. In the majority of these studies the mode of exercise incorporated during the recovery phase was similar to that used to produce lactate in the first instance. In our study we were interested in the effectiveness of contrasting modes of exercise on removal rates of lactate. Our results are in broad agreement with others which have shown that active exercise is more effective than passive exercise in removing lactate. However, it was also demonstrated that when lactate was produced through exhaustive arm work, reduced intensity arm work during the recovery phase was less effective in removing lactate than leg exercise. Indeed, in our data there was seen to be no significant difference between light arm recovery

exercise and passive rest. This finding, which is in contrast to what was expected, might be explained by the fact that the nature of the arm exercise was discontinuous and it has been demonstrated elsewhere³ that lactate removal is more effective during continuous rather than intermittent activity.

These findings are particularly interesting to slalom canoeists and are perhaps more relevant to them during training sessions than during competition for the following reasons. During an event a slalom competitor, who is allowed two competition runs, competes for a maximum of 2 min during each run. The second run occurs after a minimum time lapse of 2 h and therefore it would seem reasonable to suppose that lactate clearance has been completed within this time span almost regardless of which recovery protocol is adopted. However, during training bouts slalom canoeists practise on agitated water, often at competition speed, incorporating numerous repetitions and sets of runs. It is suggested that if recovery periods, particularly between paddling sets, incorporate activity off the water involving leg work for a period of approximately 30 min, then the subject would be in better physiological shape for performing more effective subsequent repetition training work.

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