

Y. Koutedakis



N. C. Craig Sharp

LACTIC ACID REMOVAL AND HEART RATE FREQUENCIES DURING RECOVERY AFTER STRENUOUS ROWING EXERCISE

Yiannis KOUTEDAKIS, BA, MA and N. C. CRAIG SHARP, BVMS, PhD, MRCVS

Human Motor Performance Laboratory, Dept. of P.E. and Sports Science, University of Birmingham, Birmingham B15 2TT

ABSTRACT

Three tests were conducted to assess the effectiveness of three different intensities of exercise both in reducing blood lactic acid (LA) levels and in influencing subjects' heart rate (HR), following a 2000 m race in a rowing boat. In the first and second tests these variables were investigated during a 13 min recovery exercise at 60% and 40% of the preceding maximum rowing speed respectively. In the third test the subjects had a resting recovery.

The results include a significant increase ($P < 0.001$) in the rate of lactate removal following the 40% recovery compared with the 60% and resting recoveries. The HRs were significantly lower during the last minute of resting recovery compared with 40% and 60% recoveries ($P < 0.001$). The same was true when 40% recovery was compared with 60% recovery ($P < 0.001$).

The present data suggest firstly that 40% of the maximum rowing speed is an appropriate pace for effective LA removal and secondly that, at least for trained rowers, 86% of their maximum HR can be taken as an indication of work of an intensity at or above anaerobic threshold.

Key words: Rowing, Anaerobic threshold, Lactic acid, Heart rates.

INTRODUCTION

The point at which blood lactate concentration begins to increase exponentially above resting values has been investigated regarding its relevance to exercise performance (Farrell et al, 1979; Rusko et al, 1980). When lactate accumulates to high levels in muscle and blood, it causes physical fatigue (Jacobs, 1981; Karlsson, 1980) and it is associated with a decrease in performance time of exhaustive exercise (Stamford et al, 1978). Therefore, the concept of the "anaerobic threshold" (AT) or the "lactate breaking point" has gained acceptance as a useful training aid (Jones and Ehsram, 1982; Scheen et al, 1981).

Lactate which accumulates as a result of exercise, may be removed from the blood by the myocardium (Åstrand and Rodahl, 1977; Whereat and Orishimo, 1973), renal medulla (Yudkin and Cohen, 1974), brain (Nemoto et al, 1974) and liver (Rowell et al, 1966) but mainly by skeletal muscles (Davies et al, 1970; Hermansen and Stensvold, 1972; McGrail et al, 1978). However, when exercise is performed after blood lactate has been elevated, there is an increased lactate uptake (Belcastro and Bonen, 1975; Bonen and Belcastro, 1976; Evans and Cureton, 1983; Stamford et al, 1981; Weltman et al, 1979). Intensity of recovery exercise (Hermansen and Stensvold, 1972; Sharp, 1982), type of exercise (Belcastro and Bonen, 1975; Bonen and Belcastro, 1976), training status (Andersen and Henriksson, 1977), and type of muscle fibre (Bonen et al, 1978; Lamb, 1978), are thought to influence blood lactate removal.

Rowing is considered to be one of the most physically demanding sports (Hagerman et al, 1978; Secher, 1983) as rowers work near their maximal VO_2 (Hagerman, 1984; McKenzie and Rhodes, 1982) for 6-8 mins by recruiting a very large muscle mass and deriving their energy needs from both aerobic and anaerobic metabolism (Hagerman et al, 1978).

However, unlike distance runners, who are usually careful not to exceed the anaerobic threshold (AT) in the early stages of the race, rowers quickly achieve extremely high energy expenditures, and therefore induce high lactate levels very early in the race (Hagerman et al, 1978; Hagerman et al, 1979). Thus the removal of lactic acid (LA) is of great interest in rowing.

Although many investigators have worked on athletes' recovery in a variety of sports, very little work exists which is directly relevant to rowers and rowing. Nevertheless, it would be very useful if rowing coaches could control their athletes' recovery by using two inexpensive and widely available measures, boat speed and HR. The purpose of this study, therefore, was to determine the most appropriate rowing speed for LA removal and its influence on subjects' HR, after a 2000 m race.

METHODS

Subjects

Seven healthy club rowers and scullers volunteered as sub-

jects. They were members of four different rowing clubs each with, at least, five years of rowing experience. They were in excellent physical condition when studied, preparing for various regattas. All of them competed in either coxed pairs or single sculls. The subjects were randomly tested three times each. Anthropometric data for the subjects appear in Table I.

TABLE I
Physical characteristics of the subjects

Subjects	Age yrs	Height cm	Weight kg	% Body fat	L.B.M. kg	
1st crew	AN	21	189.4	84.4	14.4	72.25
	BC	20	186.1	83.2	13.4	72.06
2nd crew	NG	23	181.3	76.4	11.8	67.39
	FF	23	187.8	85.1	13.8	73.36
3rd Crew	DN	23	182.5	79.6	14.5	68.06
4th Crew	JK	24	179.4	77.3	13.1	67.18
5th Crew	JM	25	190.1	83.5	15.3	70.73
Range		20-25	179.4-190.1	76.4-85.1	11.8-15.3	67.18-73.36
\bar{X}		22.71	185.22	81.35	13.75	70.14
S.D. _{n-1}		1.70	4.19	3.54	1.13	2.56

First Test

At the completion of warm-up, the subjects performed a 2000 m race to exhaustion. Immediately afterwards they were asked to row the same distance (2000 m) at 60% of their maximum speed, by reducing stroke rate from 38 to 22/min. During this "active recovery", three capillary blood samples were taken from each subject at the 1st, 5th and 13th minute by YK, following in a power boat which drew alongside. The samples were deproteinised and then placed in an ice box for temporary storage. Blood lactic acid concentrations were measured following the Lactate Dehydrogenase and NAD method using the Boehringer Mannheim Diagnostic kit. The subjects' HRs were recorded every 30 seconds and simultaneously every 250 m of rowing using the Hewlett Packard telemetry system.

Second Test

This test took place at the same time of day, four to five days later, using the same boats, oars and subjects. The same procedure as above was followed here, the only difference

being that the athletes were asked to "recover" at 40% of their maximum rowing speed.

Third Test

This was administered four to six days after the second test and the rowers were given a passive recovery after the end of the races. The number of blood samples and the overall procedure were identical to the other tests.

The statistical analyses performed were the paired t-tests for the last minute of the three different recoveries and referred to both LA and HR relative (%) values. Differences of $P < 0.05$ were considered significant.

RESULTS

Blood LA concentrations (mmol.l^{-1}) and HRs (beats.min^{-1}) were expressed relative to the post-exercise values (100%, Tables II, III).

TABLE III
Mean LA concentrations (mmol.l^{-1}), HRs (beats.min^{-1}) and their relative (%) values for the first and thirteenth minute of recovery*

	Recovery			
	Lactic Acid		Heart Rate	
	1st min	13th min	1st min	13th min
First Test	12.22	7.78	196.71	169.14
	1.09	1.38	7.47	3.33
(60% of max rowing speed)	100	64.37	100	86.08*
		14.34		3.54
Second Test	12.47	6.08	199.28	138
	0.96	1.07	8.03	4.61
(40% of max rowing speed)	100	48.72	100	69.35*
		6.67		4.15
Third Test	12.61	8.05	196.42	87.23
	0.94	0.96	7.16	7.88
(Resting recovery)	100	63.84	100	44.28*
		6.39		2.94

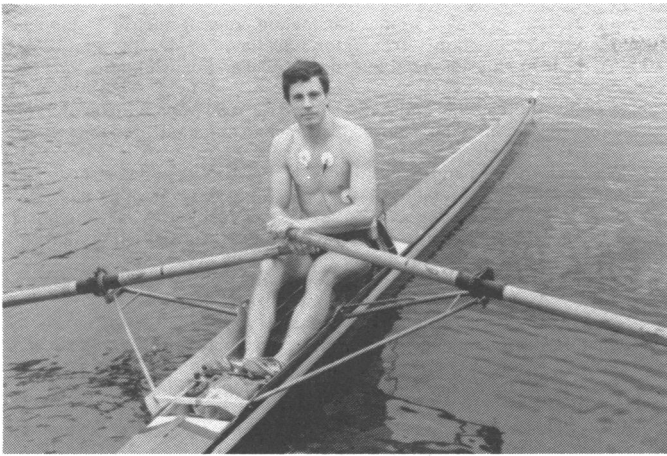
* $N = \bar{X}$, S.D._{n-1}

* significantly different, $P < 0.001$

The LA removal rates during the 40% recovery period were significantly faster than during the resting and 60% recoveries ($p < 0.001$). Blood LA concentrations were reduced to 48.7% of the initial post-exercise samples within 13 minutes during the 40% recovery. The corresponding values for the resting and 60% recoveries were 63.8% and 64.4% respectively.

TABLE II
Individual relative LA concentrations and HR

Subjects	60% recovery		40% recovery		Resting recovery	
	LA	HR	LA	HR	LA	HR
	% post race	% post race	% post race	% post race	% post race	% post race
First crew (2+)	AN	87.87 / 83.9	54.09 / 71.13	73.58 / 45.95		
	BC	62.23 / 89.23	39.13 / 66.32	61.32 / 47.14		
Second crew (2+)	NG	68.81 / 83.33	57.75 / 65.07	66.42 / 43.5		
	FF	50.60 / 88.94	45.43 / 66.82	56.20 / 44.44		
Third crew (IX)	DN	43.63 / 80.28	42.82 / 77.12	64.30 / 42.26		
Fourth crew (IX)	JK	68.56 / 88.29	53.14 / 71.28	68.66 / 47.93		
Fifth crew (IX)	JM	68.90 / 88.60	48.67 / 67.78	56.37 / 39.47		
Range		43.63-87.87 / 80.28-89.23	39.13-57.75 / 65.07-77.12	56.20-73.58 / 39.47-47.93		
\bar{X}		64.37 / 86.08	48.72 / 69.36	63.84 / 44.38		
SD _{n-1}		14.34 / 3.54	6.67 / 4.15	6.39 / 2.94		



The HRs were also significantly lower during the last minute of the 40% recovery compared to the 60% recovery ($p < 0.001$). The same was true when resting recovery was compared to 40% and 60% recovery ($p < 0.001$). In the final minute (13th) of the three different recoveries the mean HR levels were reduced to 86.1%, 69.4%, and 44.4% for the 60%, 40% and rest recovery, relative to their immediate post-exercise HR values (Table III).

DISCUSSION

Lactic Acid Removal

The removal of LA from muscle and blood following strenuous physical activity is an integral part of the recovery process. There is good agreement that, within limits (Boileau et al, 1983), an active recovery promotes the removal of blood lactate better than a resting recovery (Belcastro and Bonen, 1975; Bonen and Belcastro, 1976; Evans and Cureton, 1983; Hermansen and Stensvold, 1972; Stamford et al, 1981; Weltman et al, 1979). This effect can be attributed to the greater turnover and metabolic clearance rate of LA during moderate exercise (Issekutz et al, 1976). The results of the present study reinforce previous work on other sports, suggesting that the rate of LA removal from the blood is augmented during active recovery compared with passive recovery. This is particularly the case when the 40% and passive recoveries were compared (Table III).

In the present study the results obtained from the 40% recovery were similar to those of Bonen and Belcastro (1976). They found that "blood LA concentrations were reduced to 50% of the initial post-exercise samples within 10 mins during the free-jogging recovery", while in the present study, LA was reduced to 49% within 13 mins, during the 40% recovery. In contrast, the remaining blood LA during the 60% recovery was 64% of the initial post-exercise samples.

Previous studies have shown that the rate of blood lactate removal increases with increased intensity of active recovery up to approximately 40% of VO_2 max (Belcastro and Bonen, 1975; Hermansen and Stensvold, 1972). Moreover, it has been observed that LA removal during active recovery is less effective at intensities above AT than below the threshold (Davies et al, 1970; Weltman et al, 1979). This is because the rate of LA production exceeds the rate of LA reduction. Indeed, at exercise intensities above the AT, not only is LA produced in greater quantity but it may be that certain removal sites become relatively ineffective in removing LA due in part to reduced blood flow (Boileau et al, 1983). Rowell et al (1966) have demonstrated reduced hepatic and splanchnic blood flow as exercise intensity increases. It could be said, therefore, that the 60%

recovery used in the present study probably provided an exercise intensity at or above the AT given that firstly, LA concentration at the 13th minute of this recovery was significantly higher compared to 40% recovery and secondly, in agreement with other research (Stamford et al, 1981), there was no difference between the 60% and resting recovery values at the same time (Table III).

Heart Rates

To direct and evaluate training, knowledge of HR at AT could prove to be a valuable aid to both coaches and oarsmen. This is because there is a greater degree of improvement in AT when working at AT intensities, than at those above or below it (Gibbons et al, 1983; Sjodin et al, 1982). Additionally, the different seasonal emphasis on developing rowers' aerobic and anaerobic capacities, illustrates the potential usefulness of HR at AT.

The results of the present study show that the mean HR value at the 13th minute of the 60% recovery was 86% of the maximum HRs. This value is similar to findings of Parkhouse et al (1982), Dressendorfer et al (1981) and Dwyer and Bybee (1983) who observed that HRs at AT expressed as a percentage of maximal cardiac frequency were 84, 86, 88 and 86.3% for trained, highly trained, normal males and normal women respectively. Other investigators, using rowing ergometers, found that the mean HR values at AT were 167 and 168 $\text{beats}\cdot\text{min}^{-1}$ for international and national rowers (Mahler et al, 1984; Mickelson and Hagerman, 1982). These HRs, however, are very close to the mean value (169.14 $\text{beats}\cdot\text{min}^{-1}$ (Table III)) found in the present study corresponding to the last minute of the 60% recovery. Finally, Tables II and III show that less LA was removed during the 60% recovery compared to resting recovery. It could be said, therefore, that during the 60% recovery the subjects used for this study worked at or above their AT; also, 86% of their maximum HR could be taken as an indication of work intensity at or above their threshold.

TABLE IV

Racing times achieved, the calculated recovery times and the speed during recovery for all crews

Exercise	1st crew (2+)	2nd crew (2+)	3rd crew (IX)	4th crew (IX)	5th crew (IX)	$\bar{X}/S.D.$ _{n-1}	
Race (min)	7.25	7.28	7.46	7.55	7.54	7.41/0.14	First Test (60% of max speed)
Recovery (min)	12.08	12.13	12.43	12.58	12.56	12.35/0.23	
Speed of recovery ($\text{metres}\cdot\text{min}^{-1}$)	165.5	164.8	160.9	158.9	159.2	161.86/3.1	
Race (min)	7.28	7.30	7.20	7.58	8.01	7.47/0.33	Second Test (40% of max speed)
Recovery (min)	18.20	18.25	18.00	19.34	20.02	18.76/0.87	
Speed of recovery ($\text{metres}\cdot\text{min}^{-1}$)	109.8	109.5	111.1	103.4	99.9	106.74/4.84	
Race (min)	7.20	7.22	8.00	7.44	7.34	7.44/0.32	Third Test (Resting recovery)
Recovery (min)	—	—	—	—	—	—	
Speed of recovery ($\text{metres}\cdot\text{min}^{-1}$)	—	—	—	—	—	—	

Lactate clearing regimes, such as described above are becoming increasingly important in the development of anaerobic power through strenuous interval training. In this context it is interesting to note that comparative "clearance" speeds for other sports investigated in the authors' laboratory are of the order of 50% for cycling, 60% for sprint canoeing and 65% for running.

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