Contribution of Anaerobic Threshold to Blood Lactate Removal during Recovery Exercise

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ABSTRACT

The purpose of the present study was to examine the contribution of anaerobic threshold (AT) to blood lactate removal during recovery exercise. Seventeen male volunteers were examined at six stages of recovery exercise corresponded to 35, 45, 55, 65, 75 and 85 %$\dot{V}O_2$max for twenty minutes, respectively. Rates of lactate removal at the six stages were not always related in parallel to exercise intensities of %$\dot{V}O_2$max. The relative intensities expressed as %$\dot{V}O_2$AT were significantly different among six stages ($P<0.01$) . The rates of lactate removal were redevided into six stages based on %$\dot{V}O_2$AT which were kept almost constant under 90%$\dot{V}O_2$AT and were decreased linearly with the increased intensities above 90%$\dot{V}O_2$AT.

We conclude that the intensity on the basis of $\dot{V}O_2$AT should be applied to the assessments of the blood lactate removal due to the recovery exercise because mechanisms related to anaerobic threshold contribute to the greater part of the capacity of lactate removal in lactate metabolism during recovery exercise.

key words : recovery exercise, blood lactate removal, %$\dot{V}O_2$max, %$\dot{V}O_2$AT

1. INTRODUCTION

Recovery exercise at a low intensity following a heavy exercise is useful to remove lactic acid more rapidly and to attenuate the fatigue in the subsequent exercise. It has been generally considered that intensities of the recovery exercise to remove the lactic acid work most effectively at 30~45%$\dot{V}O_2$max [1, 4, 6, 17].

However, it was reported that long distance runners and endurance-trained athletes had the high rates of blood lactate removal (disappearance) in spite of high intensity of 63~70%

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$\dot{V}O_2$max during the recovery exercise [10,16]. These findings suggest that relative intensities of 30~45%$\dot{V}O_2$max are not always optimal at intensities of recovery exercise, when assessing lactate removal during recovery exercise in heterogeneous group.

The exercise intensity expressed as %$\dot{V}O_2$max is exponentially, not linearly related to blood lactate accumulation. This means that the estimation of blood lactate removal from %$\dot{V}O_2$max intensity of recovery exercise could be influenced by the levels of anaerobic threshold. Therefore, if $\dot{V}O_2$ during recovery exercise is devided by $\dot{V}O_2$AT, it seems to be worth to clarify how the exercise intensity of %$\dot{V}O_2$AT is related to the rate of lactate removal.

The purpose of the present study is to examine the contribution of anaerobic threshold to the rate of blood lactate removal during recovery exercise.

2. METHODS

Subjects.

Seventeen male volunteers participated in the present study. Six of the subjects were sedentary healthy students, and the others three sprinters and eight long distance runners, who perform training every day regularly. Mean and standard error (SE) of their age, height and body mass,$\dot{V}O_2$max and $\dot{V}O_2$AT are shown in Table 1. The possible risks of the study were informed to the subjects before their voluntary consent was obtained.

Table 1.Means, standard errors(SE) and minimal and maximal values of physical charac teristics and $\dot{V}O_2$max,$\dot{V}O_2$AT and %AT obtained during maximal incremental exercise.

parameter n=17	unit	mean	SE	mini.	max.
Age	*yrs*	20.8	0.48	18	25
Height	*cm*	171.3	1.60	159	182
Body mass	*kg*	60.0	1.30	50.9	70.7
$\dot{V}O_2$max	*ml.min^{-1}*	3383	115.5	2486	4042
$\dot{V}O_2$max /W	*ml.kg^{-1}. min^{-1}*	56.9	2.0	39.8	69.6
$\dot{V}O_2$AT	*ml min^{-1}*	2212	122.0	1355	3128
$\dot{V}O_2$AT/W	*ml.kg^{-1} min^{-1}*	36.6	2.18	19.9	52.7
%AT	%	64.9	2.18	54.3	81.5

$\dot{V}o_2$max, maximal oxygen uptake ; $\dot{V}O_2$AT, oxygen uptake at anaerobic threshold
%AT, oxygen uptake at anaerobic threshold / maximal oxygen uptake * 100

Exercise protocol.

<Experiment I> Maximal incremental exercise test was performed on a Monark cycle ergometer equipped with toe clips to determine maximal oxygen uptake ($\dot{V}O_2max$) and oxygen uptake at anaerobic threshold ($\dot{V}O_2AT$), pedaling rate at 60 rpm. The work rate was initially set at 0 kpm/min for four minutes and subsequently was increased progressively at 180 kpm/min every minute and subjects were instructed to pedal rhythmically in harmony with a metronome until each subject's voluntary exhaustion.

<Experiment II> On another day the six stages of recovery exercise were carried out at intensities of 35, 45, 55, 65, 75 and 85 %$\dot{V}O_2max$ for twenty minutes, respectively. The intensities were in the range from a low relative intensity at which lactate is removed more effectively to comparatively high relative intensity, following a main exercise at 90%$\dot{V}O_2max$ for three minutes. Eight of all subjects performed twice recovery exercises that were loaded at low and high intensities and nine subjects did a exercise at low or high intensities once.

Expired gas was determined continuously through experiments I and II by an automatic gas analyzer (Aerobic Processor 391, Sanei Ins. Tokyo Japan), by which Ventilation ($\dot{V}E$), oxygen uptake ($\dot{V}O_2$), carbon dioxide output ($\dot{V}CO_2$) respiratory rate (RR) and respiratory exchange ratio (R) were obtained and calculated. The calibration of this analyzer was carried out by the known gases in both before and after measurements.

A 2*l*-gauge x 19 mm butterfly needle was inserted and fixed in a radial vein. After the dead spaces of the needle, tube and cock were flushed by drawing some of blood into a syringe, 2.0 ml blood samples were drawn through three-way cock into another syringe. Saline was infused through the needle, tube and cock in order to prevent the blood coagulation. Blood samples in experiment I were drawn at three minutes after start of the incremental exercise, followed in every minute until the exhaustion. The samples in experiment II were drawn at third minute in the main exercise and then at 5th, 10th, 15th and 20th minute in the recovery exercise. The 2.0 ml samples for lactate concentration analysis were mixed with 2.0 ml cold perchloric acid(1.ON) for the deproteinization. The remainder after the centrifuge was taken and frozen. Lactate concentration was measured by using an enzymatic method[9].

The rate of blood lactate removal was calculated by a linear regression (y=Ax+B) between time (min :x) and blood lactate ($mmol \cdot l^{-1}$:y) during recovery exercise. The gradient of "A" in the linear regression was used as the rate of blood lactate removal according to the previous studies[1,17,20]. The anaerobic threshold was detected by the gas parameters ($\dot{V}E$, $\dot{V}E/\dot{V}CO_2$, $\dot{V}E/\dot{V}O_2$, R) and blood Lactate concentration [5,22].

Statistics.

The statistical significance's of differences of parameters among the six stages of recovery exercise were tested by one factor analysis of variation (ANOVA) and the Person's product correlation coefficient was calculated in the all correctional analyses. The relationships between rate of lactate removal and exercise intensities of %$\dot{V}O_2$max and %$\dot{V}O_2$AT were assessed by a polynomial regression. The statistical significance level was accepted at $P<0.05$ for all tests.

3. RESULTS

Means and SE of absolute $\dot{V}O_2$ ($l \cdot min^{-1}$), relative intensities expressed as %$\dot{V}O_2$max and %$\dot{V}O_2$AT and each rate of blood lactate removal corresponded to %$\dot{V}O_2$max and %$\dot{V}O_2$AT

Table 2. Means and standard errors of the intensities of %$\dot{V}O_2$max and %$\dot{V}O_2$AT and rates of blood lactate removal during recovery exercise.

Stages		$\dot{V}O_2$# ml.min^{-1}	% $\dot{V}O_2$max* %	rate of lactate removal mmol . l^{-1}. min^{-1}		%$\dot{V}O_2$AT * %	rate of lactate removal mmol . l^{-1}. min^{-1}
I	n=4	1241± 73.4	38.7±0.44	-0.401±0.0376	n=3	54.3± 2.08	-0.409±0.0491
II	n=4	1418±115.8	44.9±1.37	-0.424±0.0184	n=4	64.6± 2.73	-0.419±0.0245
III	n=3	2011±203.9	56.6±1.17	-0.267±0.0319	n=3	85.7± 2.55	-0.383±0.0128
IV	n=5	2374±145.4	66.5±1.42	-0.296±0.0339	n=5	96.1±1.08	-0.246±0.0228
V	n=5	2644± 88.1	75.4±1.01	-0.160±0.0561	n=5	105.3 ±0.96	-0.228±0.0259
VI	n=4	2460±121.0	86.1±2.26	-0.030±0.0345	n=5	148.7± 4.07	-0.016±0.0302

%$\dot{V}O_2$max, percentage of $\dot{V}O_2$ during recovery exercise to $\dot{V}O_2$max.
%$\dot{V}O_2$AT , percentage of $\dot{V}O_2$ during recovery exercise to $\dot{V}O_2$AT.
oxygen uptake of six stages of recovery exercise are the averaged values of $\dot{V}O_2$ at 5th,10th,15th and 20th minutes.
* $P < 0.01$, significantly difference among six stages of %$\dot{V}O_2$max and % $\dot{V}O_2$AT in recovery exercises according to ANOVA with one factor.

are shown in the six stages of the recovery exercise in Table 2. The relative intensities expressed as %$\dot{V}O_2$max were significantly different among six stages according to ANOVA($P<0.01$). Blood lactate removal represented the highest values of 0.4014 and 0.4241 mmol $\cdot$ l$^{-1}\cdot$ min^{-1} in stages I and II at 38.7 ~ 44.9 %$\dot{V}O_2$max, but the rates of lactate removal were not always related in parallel to six stages of %$\dot{V}O_2$max (Figure 1). The relative intensities expressed as %$\dot{V}O_2$AT were significantly different among six stages ($P<0.01$) and rates of lactate removal in six stages were combined again. As shown in Figure 2, the highest values of blood lactate removal were almost same values of 0.4094~0.3833 mmol$\cdot$l$^{-1}\cdot$ min^{-1} in spite of the increased stages of 54.3 ~ 85.7 %$\dot{V}O_2$AT, and the rates under stage III was significantly different from those above stage IV in Table 3 ($P< 0.01$).

Table 3. Significant differences of rates of blood lactate removal among six stages of %$\dot{V}O_2$max and %$\dot{V}O_2$AT according to ANOVA with one factor

stage II	stage III	stage IV	stage V	stage VI	%VO2max
n s	*	ns	* *	* *	stage I
	*	*	* *	* *	stage II
		n s	n s	* *	stage III
			*	* *	stage IV
				*	stage V

stage II	stage III	stage IV	stage V	stage VI	%VO2AT
n s	n s	* *	* *	* *	stage I
	n s	* *	* *	* *	stage II
		* *	* *	* *	stage III
			n s	* *	stage IV
				* *	stage V

*: P<0.05, significant difference among six stages with Fisher's ANOVA.

**: P<0.01, significant difference among six stages with Fisher's ANOVA.

ns: no significant difference.

The exercise intensity of %$\dot{V}O_2$max was obtained to correlate significantly with the rate of lactate removal in recovery exercise, using a secondary polynomial regression equation (r=0.871, P<0.001) as shown in Figure 3. As shown in Figure 4, the values of blood lactate removal equivalent to the intensities of $\dot{V}O_2$AT were plotted to determine a new relationship between the intensity on the basis of AT and rate of blood lactate removal. It was found that the intensity of %$\dot{V}O_2$AT correlated significantly with the rate of lactate removal (r=0.917, P<0.001). The SE est ($\pm$ 0.0650 mmol·l^{-1}·min^{-1}) for the relationship between the rate of lactate removal and the intensity of %$\dot{V}O_2$AT was smaller than the SE est in that ($\pm$ 0.0801 mmol·l^{-1} ·min $^{-1}$) obtained in Figure 3.

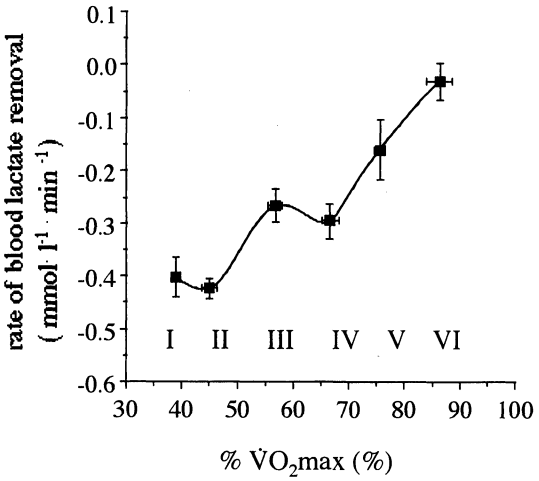

Figure 1. The relationship between means and SE of %$\dot{V}O_2$max and means and SE of rate of blood lactate removal in six stages of recovery exercise

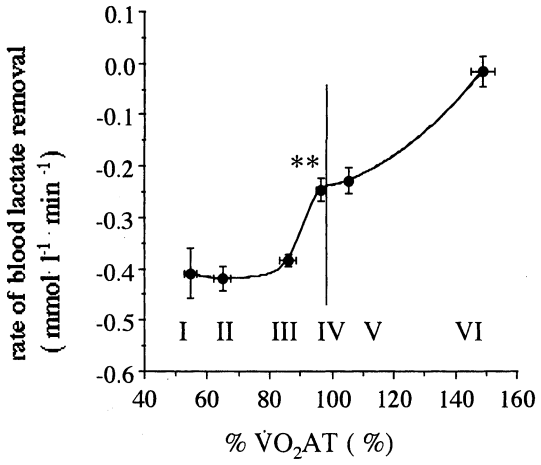

Figure 2. The relationship between means and SE of %V̇O2AT and means and SE of rate of blood lactate removal in six stages of recovery exercise. *P<0.01,stages Ⅰ,Ⅱand Ⅲ are significantly different from stage Ⅳaccording to ANOVA.

4. DISCUSSION

In the present study, the relationship between the intensity of %V̇O2max and the rate of blood lactate removal is similar to that of the previous studies [1, 4, 6, 15,17]. On the other hand, rates of lactate removal were kept constant under the intensities of 90%V̇O2AT and were decreased linearly with the increased intensities above 90%V̇O2AT. We suggest, therefore, that some physiological important factors are included into the intensity of %V̇O2AT. They would be (1) lactate removal relates deeply to the mechanism of lactate production and/or lactate mechanism and (2) catecholamine secretion and muscular blood flow relate to the exercise intensity.

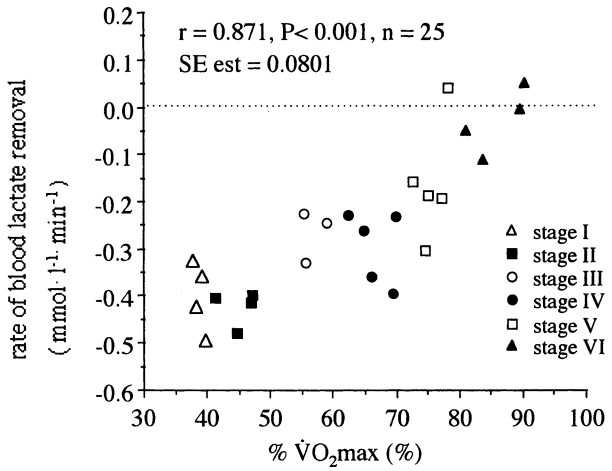

Figure 3. The relationship between %V̇O2max and rate of blood lactate removal in six stages of recovery exercise. The secondary polynomial regression equotion is calculated in the relationship between %V̇O2max and blood lactate removal($y=-0.25457-0.0092x+1.3717e-4x^2$).

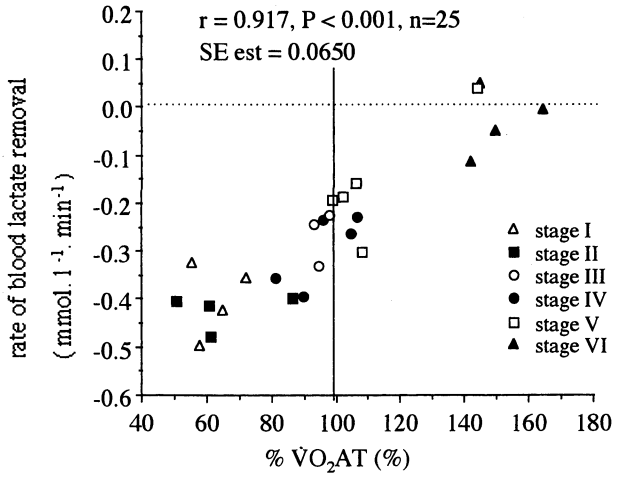

Figure 4. The relationship between %$\dot{V}O_2$AT and rate of blood lactate removal in six stages of recovery exercise. The secondary polynomial regression equotion is calculated in the relationship between %$\dot{V}O_2$AT and blood lactate removal($y=-0.62328+0.0029x+7.373e\text{-}6x^2$).

Firstly, the subjects used in this study were consisted of long distance runners, sprinters and sedentary men so that %AT was extended a wide range of 54.3 ~ 81.5%. $\dot{V}O_2$AT and %AT in long distance runners were signifcantly higher than those in sedentary men [19,23]. It is suggested that our subjects have different capacities of lactate metabolism. Ivy et al. [12] have indicated that the capacity of muscle homogenates to oxidize pyruvate was significantly related to $\dot{V}O_2$ at lactate threshold ($\dot{V}O_2$LT), and that a significant correlation was found between %ST fibers and $\dot{V}O_2$LT. Considering the muscle fiber composition and blood lactate removal, it was indicated that %ST fibers were significantly correlated to the rates of blood lactate removal [2]. Using a isotopic techniques directly, Donovan and Pagliassotti [7] reported that the efficiency of lactate removal was enhanced by endurance training. We guessed that the subjects who had high values of $\dot{V}O_2$AT would reveal the high rate of blood lactate removal.

Anaerobic threshold implies the point at which lactate appearance exceeds lactate disappearance, and lactate appearance during exercise comes from lactate production in muscle and lactate disappearance is derived from the difference of lactate production and lactate removal in muscle and blood [3]. Lactate during leg exercise was taken up the inactive forearm muscle even though the working muscle is a major site of blood lactate removal during exercise [18,21]. In the present study, the decline of lactate in blood means that while some lactate formed in working legs muscle during recovery exercise is released into the venous blood, the greater part of the released lactate is removed from the arterial blood to active and inactive muscle [11,13].

Secondly, the muscle blood flow is a key component for the effective blood lactate removal, because lactate removal and muscle blood flow is composed of lactate clearance [3,13]. Lactate clearance is an important factor to determine the fate of lactate produced during exercise in a whole body. Catecholamine that stimulate vascular-dilution control the muscle blood flow during exercise. The epinephrine and norepinephrine concentrations were closely related to the exercise intensity of $\%\dot{V}O_2max$ [8]. However, Lehmann et al. [14] indicated that catecholamine began to increase exponentially at intensities above AT during the incremental exercise. From those findings, in the subjects who have the same $\dot{V}O_2max$ but the different AT, the activity of catecholamine secretion is expected to be different between subject to subject in spite of the same intensity of $\%\dot{V}O_2max$. Therefore, although a given intensity is a better way to keep high blood flow, the intensity exceeding AT leads the excess lactate accumulation in parallel to the increased catecholamine and may inhibit the faster lactate removal during the recovery exercise.

As mentioned above, we discussed the relationships between lactate removal due to the recovery exercise and two sorts of exercise intensity. In the assessments of lactate removal during the recovery exercise, since the $\%\dot{V}O_2AT$ reflects a profile of lactate metabolism during exercise, it is necessary to consider the relation of lactate production and lactate removal in connection with the intensity of exercise. It is indicated in heterogeneous group that the application of intensity of $\dot{V}O_2max$ to recovery exercise is inadequate for the assessments of blood lactate removal. Consequently, the exercise intensity based on the AT related to lactate metabolism should be employed in the recovery exercise.

The results of the present study showed that blood lactate removal was more strongly related to the intensity of $\%\dot{V}O_2AT$ than that of $\%\dot{V}O_2max$ in the recovery exercise. It seems likely that blood lactate removal estimated in a given intensity of $\%\dot{V}O_2max$ in recovery exercise could be influenced by the AT levels. Consequently, it is concluded that the intensity on the basis of AT could be valid for the study of the effective blood lactate removal in the recovery exercise.

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