Brit.J.Sports Med.: 1979, 13, 165-169

BLOOD LACTATE CONCENTRATIONS DURING INCREMENTAL WORK BEFORE AND AFTER MAXIMUM EXERCISE

H. A. DAVIS, BVSc, MMedVet, G. C. GASS, MSc, PhD

Department of Biological Sciences, Cumberland College of Health Sciences, PO Box 170, Lidcombe, NSW 2141, AUSTRALIA

ABSTRACT

Five male subjects performed three successive incremental work tests on an electronically braked cycle ergometer. The first and second tests were separated by thirty minutes of rest, the second and third by three minutes of maximum work. During the third test, venous blood lactate concentrations were still decreasing at work rates where they were increasing during the first two tests. The work rate at which rapid increases in lactate concentrations occurred during the final test coincided with the work rate where rapid increases occurred in the two initial tests. It was concluded that this point represented a threshold where a balance existed between removal and release of lactate from and into the plasma compartment, and did not coincide with the anaerobic threshold. It is postulated that steady state work at levels above this threshold would result in a continuous increase in venous lactate concentration.

INTRODUCTION

Maximum oxygen consumption ($\dot{V}O_2$ max) has been accepted as a useful measure of endurance capacity in events where oxidative energy release predominates, Saltin and Åstrand (1967), Shephard, et al (1968). Participating athletes vary in the percentage of $\dot{V}O_2$ max which they are able to utilise, and train to increase this ability (Åstrand and Rodahl 1977).

Another measure which has been used as an index of endurance performance is the anaerobic threshold (AT). When workload is incremented gradually during exercise, there is a stage at which activation of anaerobic metabolism is followed by release of lactate from the muscle into the blood, Gollnick and Hermanson (1973). The onset of this process is termed the AT, and may be expressed as a percentage of $\dot{V}O_2$ max, or as a work rate, at which it occurs. The AT has been defined as the level of work or $\dot{V}O_2$ just below that at which metabolic acidosis occurs, Wasserman, et al (1973). The AT may be determined by means of serial venous lactate measures and/or respiratory gas exchange during exercise (Wasserman, et al, 1973), Davis, et al (1976).

It has been noted that individuals may work for considerable periods (30 minutes or longer) at work rates above their AT (unpublished results). It has also been demonstrated that lactic acid removal rates after high intensity work are increased with lower intensities of work during the recovery period (Belcastro and Bonen 1975). Nagle, et al (1970) investigated venous lactate levels during steady state work at varying percentages of $\dot{V}O_2$ max and found with increases in work rate a change from slight increases in lactate maintained over 60 minutes, to larger increases which also plateaued, to finally a continual increase over 30 minutes at high work rates. The AT cannot predict this type of change during steady state work.

This study was designed to investigate the changes in AT and venous lactate levels during repeated incremental work tests before and after elevating blood lactate levels by means of high intensity exercise.

METHOD

Five male volunteers in good general health participated in the study. Their physical characteristics are shown in Table II. All of these subjects had undergone systematic training for at least sixth months prior to the investigation.

Respiratory gas samples were collected via a low resistance Hans Rudolph valve #2700 through a mixing chamber cooled by ice, and by means of a Tissot calibrated dry gas meter (Parkinson Cowan). Paramagnetic oxygen and infrared carbon-dioxide analysers continuously sampled expired air from the ice cooled mixing chamber at a rate of 1.25 $L.min^{-1}$ and 1.00 $L.min^{-1}$ respectively. The analysed sample of expired air was pumped back into the expired air volume. Each analyser was calibrated frequently with mixtures of chemically analysed gas. AT was calculated during each test using the method of Davis, et al (1976).

All testing was done with the subject sitting in the upright position on a cycle ergometer (Siemens 380b). The power output on this ergometer is constant and independent of pedalling speeds.

Venous blood samples were obtained from an antecubital vein through indwelling 19 gauge siliconised needles with 9 cm of tubing and a removable resealing

injection site (Abbott Laboratories). Where blood samples were obtained at longer intervals than one minute the cannula was kept patent with sterile heparinised saline (5000 IU/L.).

Prior to sampling venous blood for lactate determination approximately one millilitre of blood was withdrawn from the sampling site and discarded, a further 1.5-2 ml of blood were withdrawn using a clean syringe, and the contents were placed into a tube containing sodium fluoride and potassium oxalate. The tube was inverted several times and exactly one millilitre was pipetted into 10% perchloric acid, shaken vigorously and frozen. Duplicate blood lactates were analysed enzymatically (Calbiochem – Behring Corp.).

The experimental design and times of venous blood sampling are shown in Table I.

TABLE I

Experimental design and venous sampling times

Time (min)	Work Rate (W)	Venous Sampling	
0	0	+	
0 – 3	50	+	
3 – 3.5	80		
3.5 – 4	110	+	
4 – 4.5	140		SECTION
4.5 – 5	170	+	A
5 – 5.5	200		
5.5 – 6	230	+	
6 – 6.5	260		
6.5 – 7	290	+	
7 – 12	rest	+	
12 – 37	rest	+	
37 – 39	REPEAT SECTION A		
49 – 52	MAXIMUM WORK (270 – 400w)		
52 – 57	rest	+	
57 – 69	REPEAT SECTION A		

TABLE II

Physical Characteristics of the Subjects

	Range	Mean	S.D.
Age (years)		33	±12.2
Height (m)		1.745	± 0.092
Weight (kg)		78.9	± 4.7

Means and standard errors were determined for blood lactate concentrations and a 't' test for related groups was used to test for significant differences.

RESULTS

Individual venous lactate concentrations are presented in Table III. Overall means and standard errors are graphed in Figure 1, with each incremental work test shown separately. The mean AT's for each incremental work test as determined by the method of Davis, et al (1976) are presented in Figure 1. The AT's as determined by respiratory gas analysis were similar in all three work tests.

During the first incremental work test, the greatest change in the rate of venous lactate accumulation occurred at a nett work rate of 140 watts. During the second test, where the initial lactate levels had not returned to the original resting levels, the work rate of 140 watts marked the time of change of decreasing to increasing venous lactate concentrations. This work rate was accepted as the anaerobic threshold, using the definition of AT as the work rate just below that at which lactate is released into the blood.

In the final test, venous lactate concentrations significantly ($P < .01$) decreased until these same work rates, and continued decreasing until a work rate of 260 watts. At work rates exceeding 260 watts the venous lactate concentrations increased in all three incremental tests.

During the first three minutes of test one, no significant changes in venous lactate concentration occurred. In contrast, the same work interval in test two produced a significant ($P < .05$) decrease in lactate and in test three produced a significant ($P < .01$) decrease. Increases in lactate levels were significant ($P < 0.01$) in the five minute rest interval after the initial test, but no significant change occurred in the last test where the lactate concentrations were higher prior to commencement of work.

None of the subjects attained a plateau of oxygen uptake during the three incremental work tests which were terminated at a rate which was insufficient to induce maximal oxygen uptake.

DISCUSSION

The major finding of this study was that, during incremental work, a range of identical work rates was associated with changing concentrations, (either an increase or decrease) in venous lactate. The direction and magnitude of these changes depended upon the initial lactate concentration. During the incremental test with high initial concentrations, a reduction in lactate concentration occurred at levels far exceeding the AT. During this latter test a second threshold (AT_2) was reached where lactate levels again increased significantly. Work rates exceeding this threshold during the first two tests were also associated with rapid lactate elevation. It is postulated that the range between the AT_1 and AT_2

TABLE III

Individual Venous Lactate Concentrations; ($m.mol.L^{-1}$)

	Time (min)	Subject 1	2	3	4	5	Mean	S.E.
	0	1.43	0.87	1.63	1.63	0.95	1.30	.16
	3	1.71	0.69	1.59	1.52	0.86	1.27	.21
	4	1.86	1.00	1.59	1.38	1.06	1.38	.16
Test 1.	5	2.71	1.10	1.76	1.72	1.35	1.73	.27
	6	3.04	1.38	2.01	2.61	2.06	2.22	.28
	7	3.41	1.73	2.30	4.30	2.44	2.84	.45
	12	5.79	3.53	4.50	5.13	3.64	4.52	.43
	37	2.50	1.91	2.25	2.81	2.41	2.38	.15
	40	2.20	1.68	2.04	2.02	1.69	1.93	.10
	41	1.90	1.42	2.04	2.04	1.69	1.82	.12
Test 2.	42	2.09	1.61	2.50	2.21	1.69	2.02	.17
	43	2.34	1.84	2.81	3.33	1.67	2.40	.31
	44	9.95	1.96	2.87	3.99	2.01	4.16	1.49
	49	12.22	2.98	6.32	7.25	2.87	6.33	1.71
	51	12.34	11.71	8.89	9.61	8.76	10.26	.74
	60	9.03	10.18	6.65	8.29	6.42	8.11	.71
	61	9.75	10.04	6.57	8.80	5.90	8.21	.84
Test 3.	62	7.77	9.06	6.34	8.49	5.29	7.39	.69
	63	7.42	9.09	6.22	8.83	4.56	7.22	.84
	64	10.41	9.15	8.23	8.29	3.99	8.01	1.08
	69	8.65	8.46	8.40	9.72	4.26	7.90	.94

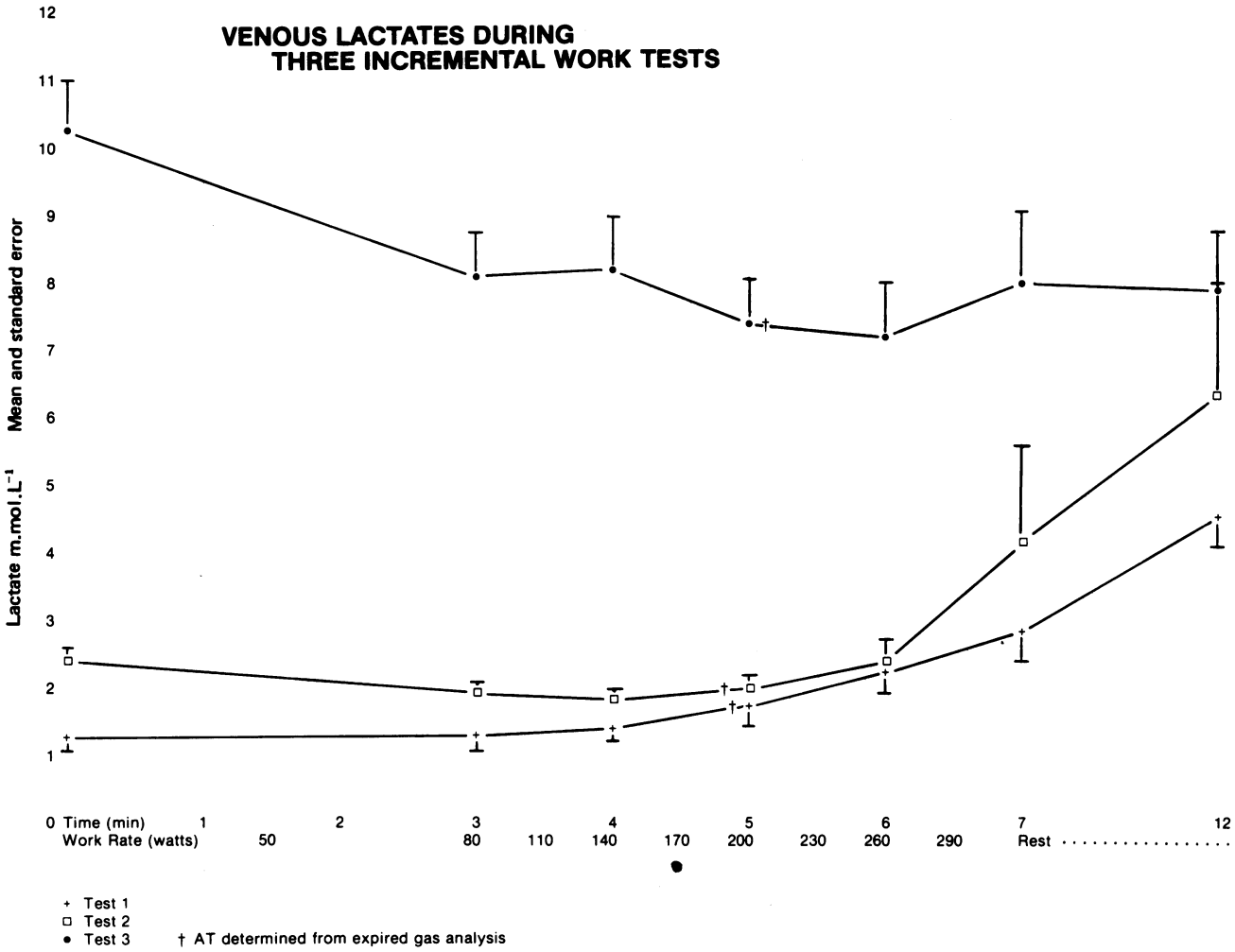
has predictive value for steady state work. Work rates below the AT will result in no increase in venous lactate; those in the range between the AT_1 and AT_2 will result in increases which will plateau; those higher than the AT_2 will result in a continuous, work limiting increase, with no plateau. It is significant that Weiser, et al (1978), using respiratory parameters for the determination of AT, found changes at two different work rates in some of their subjects.

Several authors McGrail, et al (1978), Hermansen and Vaage, (1978), Belcastro and Bonen, (1975), Bonen and Belcastro, (1976) and Davies et al (1970) have shown a work-rate dependent removal of venous lactate during exercise at submaximal loads. Removal occurs primarily into skeletal muscle McGrail et al (1978). A comparison of self-selected intensities of work and lactate removal rates has been made, Bonen and Belcastro, (1976). Within limits, the removal rate of lactate increases with increasing exercise intensity. The present study found that at low work rates (50 watts) the rate of the removal of lactate was dependent on the initial lactate concentration. High initial concentrations resulted in significant increases in the rate of lactate removal.

A post-exercise increase in blood lactate during rest has been documented, Hermansen and Vaage (1977), with peak concentration occurring approximately five minutes post exercise. This typical pattern occurred during the first two incremental tests of the present study. During the final test, no significant increase in post exercise blood lactate occurred. This may have been the result of prior equilibration of muscle and venous lactate concentrations. Lactate disappearance during recovery is far more rapid in muscle than blood, Hermansen and Vaage, (1977), and an inward concentration gradient would have been established.

It was surprising that the percentage of oxygen in expired air followed exactly the same response pattern during the three tests. This has been used in the determination of the AT, (Davis, et al 1976), on the basis of ventilation increasing out of proportion to oxygen uptake at the AT, due to the metabolic acidosis. However, a central hydrogen ion concentration respiratory stimulus to respiration at the AT has been queried by Bisgard et al, (1978). They found no increase in the hydrogen concentration of cerebrospinal fluid in ponies during different intensities of treadmill exercise while determining the AT. They concluded that the increase in ventilation was unlikely to have been caused by central stimulation of the medullary chemoreceptors.

It is concluded that the AT is an index of onset of



anaerobiosis during incremental work, but does not describe a variable plasma lactate concentration response during repeated bouts of incremental work. A second threshold (AT_2) has been demonstrated. At work rates above this threshold invariable increase in venous lactate concentration may be anticipated during intermittent incremental work. It is postulated that the range between AT_1 and AT_2 may have predictive value for estimation of venous lactate concentration responses during steady state work.

REFERENCES

Åstrand, P.-O. and Rodahl, K. 1977. "Textbook of Work Physiology". New York, McGraw Hill, 2nd. ed.

Belcastro, A. N. and Bonen, A. 1975. "Lactic acid removal rates during controlled and uncontrolled recovery exercise". J.Appl.Physiol. 39: 932-936.

Bonen, A. and Belcastro, A. N. 1976. "Comparison of self-selected recovery methods on lactic acid removal rates". Med.Sci.Sports 8: 176-178.

Davies, C. T. M., Knibbs, A. V. and Musgrove, L. 1970. "The rate of lactic acid removal in relation to different baselines of recovery exercise". Int.Z.Angew.Physiol. 28: 155-161.

Davis, J. A., Vodak, P., Wilmore, J. H., Vodak, J. and Kurtz, P. 1976. "Anaerobic threshold and maximal aerobic power for three modes of exercise". J.Appl.Physiol. 41: 544-550.

Gollnick, P. D., and Hermansen, L. 1973. "Biochemical adaptations to exercise: anaerobic metabolism". Ex.Sports Sci.Rev. 1: 1-43.

Hermansen, L. and Vaage, O. 1977. "Lactate disappearance and glycogen synthesis in human muscle after maximal exercise". Am.J.Physiol. 223: E422-429.

McGrail, J. C., Bonen, A. and Belcastro, A. N. 1978. "Dependence of lactate removal on muscle metabolism in man". Eur.J.Appl.Physiol. 39: 89-97.

Nagle, F., Robinhold, D., Howley, E., Daniels, J., Baptista, G. and Stoedefalke, K. "Lactic acid accumulation during running at submaximal aerobic demands". Med.Sci.Sports 2: 182-186.

Saltin, B. and Åstrand, P.-O. 1967. "Maximal oxygen uptake in athletes". J.Appl.Physiol. 23: 353-358.

Shephard, R. J., Allen, C., Benade, A. J. S., Davies, C. T. M., Hedman, R., Merriman, J. E., Myhre, K., di Prampero, P. E. and Simmons, R. 1968. "The maximum oxygen uptake. An international reference standard of cardiorespiratory fitness". Bull.WHO 38: 757-764.

Wasserman, K., Whipp, B. J. Koyal, S. N. and Beaver, W. L. 1973. "Anaerobic threshold and respiratory gas exchange during exercise". J.Appl.Physiol. 35: 236-243.

Weiser, P. C., Norton, C. H. and Krogh, L. A. 1978. "Anaerobic threshold and the running speed for 3.2 km". Med.Sci.Sports 10: 43.

BOOK REVIEW

Doreen A. CAMILLERI, MCSP

The Physiotherapy Clinic – Tagliaferro Centre, High Street, Sliema, Malta

CINQUANTA ANNI DI ATTIVITA

The Federazione Medica Sportiva Italiana (FMSI) is this year celebrating its 50th Anniversary.

The Federation has published a book, "Fifty Years of Activities" to mark the occasion. The Book, compiled by the Secretary of the Federation, Doctor Franco Barbieri, gives an extensive view of the performance of the FMSI since its foundation in 1929.

Chapters covering the historical evaluation, preventive care in sport, social and education aspects of Sport, Parliamentary Legislation and general activities are amply supplied with charts, tables and photographs to illustrate the wide range of activities.

In association with the Comitato Olimpico Nazionale Italiano (CONI) the FMSI has set up various centres, clinics and laboratories throughout Italy.

The role of the Sports Doctor is now changing to a more positive role in prevention of injury and is no longer restricted to treatment of injuries. To facilitate this, the FMSI has succeeded in securing legislative measures empowering it to conduct medical checks on athletes, and is at present pressing for further legislation in order to conduct spot-checks whilst athletes are in training.

The FMSI organises and conducts seminars and congresses for trainers, coaches, physiotherapists and masseurs in order to ascertain a high level of training of these personnel who have direct contact with the athlete. Checks are also made on middle age non-competitive sportsmen in order to control and prevent accidents prevalent in that age group.

The FMSI also plays an important role in controlling the drug-taking abuses found in sport where in top class sport any means are resorted to in order to achieve victory.

Doreen Camilleri