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Blood lactate concentrations during a constant load at an intensity corresponding to the aerobic-anaerobic threshold in young athletes.

by A. Ascensão, P. Santos, J. Magalhães, J. Oliveira, J. A. Maia, J.M.C Soares

ABSTRACT

It is believed that in adults the workload corresponding to a blood lactate concentration (BLC) of 4 mmol/l, determined by the aerobic-anaerobic threshold, may be maintained for as long as 30min at a constant workload (steady-state BLC). However, there is a lack of studies analysing whether such a phenomenon also occurs in young athletes.

The purposes of this study were: (i) to investigate the existence of a steady-state of BLC during 30min of constant exercise (at an intensity corresponding to 4 mmol/l) in young athletes, and (ii) to assess possible intra-individual lactate differences during the test.

Thirteen young athletes (age: 16.07±1.38 yrs; weight: 61.0±6.69 kg; height: 171.3±5.6 cm) were evaluated during both an incremental test and a constant workload test. The incremental step test was used to determine the workload corresponding to 4mmol/l of BLC (V4). After 3 days, the subjects performed a 30min constant load test at the previously determined V4. During both tests capillary blood was taken from the ear lobe and immediately analysed using an enzymatic blood analyser (YSI 1500L-Sport). During the constant test blood samples were taken after 5, 10, 15, 20, 25 and 30 minutes and the statistical analysis included a repeated measure Anova.

The mean V4 value was 3.9±0.28 m/s. Two of the thirteen subjects were not able to finish the 30 minute test (the final BLC was 9.82 and 7.25 mmol/l, respectively). According to criteria established by Heck et al (1985), the remaining subjects completed the test with a mean steady-state BLC of 4.15±1.11 mmol/l. The mean BLC at the different stages (5, 10, 15, 20, 25 and 30 minutes) of the constant test was, respectively: 4.21, 4.50, 4.67, 4.57, 4.87 and 4.25 mmol/l. There were no significant differences in the repeated observations (F(5,6) =1.035 ; p =0.474), indicating that no evidence of intra-individual BLC differences during the 30 min test exists. It can thus be concluded that a blood lactate steady-state may be achieved at intensities corresponding to 4mmol/l in young athletes.

AUTHOR

António Ascensão - Assistant Lecturer at the Sports Biology Department, Faculty of Sport Sciences and Physical Education of the University of Porto, Portugal

His day-to-day work includes long-term physiological testing in both elite and young athletes. Amongst other subject areas within exercise physiology and biochemistry, a special interest area for him has been a focus on training controls for the aerobic capacity of runners.

Introduction

The anaerobic threshold has been widely regarded as the transition between aerobic and anaerobic metabolism (Heck et al. 1985_a; Mader 1991; Mader et al. 1976; Hartmann and Mader 1994). The workload in relation to the anaerobic threshold can be assumed as the highest workload carried out by the overall oxidative metabolism. According to Heck et al. (1985_a) and Mader et al. (1976), a BLC corresponding to 4 mmol/l has been set as the most accurate criteria for anaerobic threshold determination. On that basis this BLC is the highest one that can be sustained during a prolonged exercise bout in steady state conditions, i.e. it corresponds to a workload intensity above which the rate of lactate production exceeds lactate clearance (Beneke et al. 1996; Hartmann and Mader 1994, Heck et al. 1985_a). Any increase in intensity above the referred workload would lead to a higher glycolytic rate compared to the rate of pyruvate oxidation (Brooks 1986). According to this assumption, an ability to maintain workloads corresponding to 4 mmol/l BLC (V_4) during a prolonged constant load test can be expected.

A high correlation was found amongst several different methods for determining the anaerobic threshold, using either incremental step tests or maximal lactate steady state (MaxLass) (Heck et al. $1985_{b,c}$) as the basis for investigation. However, some experiments (Foxdal et al. 1996; Fohrenbach et al. 1987) have shown that V_4 cannot always be maintained in steady state conditions during a prolonged constant load. In fact, extrinsic and intrinsic factors such as aerobic capacity, training adaptations induced by different training programmes, maturation and age may influence MaxLass (Beneke et al. 1996; Beneke and von Duvillard 1996; Foxdal et al. 1996; Kruger et al. 1990; Williams et al. 1990).

On the subject of age, several studies (Pfitzinger and Freedson $1997_{a,b}$; Pianosi et al. 1995; Williams et al. 1990) reported some changes in the aerobic and anaerobic metabolic profile during growth such as glycolytic and oxidative enzymes, which may influence BLC during sub-maximal exercise intensities.

Moreover, the rate of lactate appearance in blood depends on several factors such as muscle fibre type composition, muscle respiratory capacity, mobilisation of energy substrates as well as the biochemical characteristics of muscle cells (Donovan and Pagliassotti 2000, Ivy et al. 1980, Green 1996, Henriksson 1996, Holloszy 1996).

Therefore, the aims of this present study were: (i) to investigate the existence of a steady-state BLC during a 30 minute bout of exercise (at an intensity corresponding to anaerobic threshold) in young athletes, and (ii) to assess possible intra-individual lactate differences during the test.

Methods

Subjects

Thirteen (13) male young athletes (16.07±1.38 yrs; 61.0±6.69 kg; 175±4.21cm) participated in the study. A signed informed consent form was required from each parent of the subjects before participation in the study. According to a prior questionnaire, all the subjects were track and field participants following a training routine of 3 sessions a week. The subjects were not involved in any exercise activities in the 3 days before and during the tests.

Testing procedures

The subjects were tested in incremental and constant running workload tests. The tests were performed with an interval of 3 days between them.

Incremental Running Step Test

The incremental step test (Mader et al. 1976) was used to determine the workload (m/s) which corresponded to 4mmol/l of BLC (V_4). The test was conducted on a 400m synthetic track, and utilised 4 running speeds (3.0 – 4.6 m/s) with 0.4 m/s increments and a minimum duration of 5.30min. Within 30 seconds of the end of each stage, capillary ear lobe blood samples were collected, after

which the subjects immediately started the new faster running stage. The regulation of the running pace within each workload stage was ensured by acoustic warning signals every 200m.

Prolonged Constant Running Test

The test was also conducted on a 400m synthetic track. The subjects performed a 30 minutes constant load test with an intensity corresponding to the previously determined V4. During the test the regulation of the running pace was ensured by a highly trained runner and also by acoustic warning signals every 100m. The test was interrupted every 5 minutes for ear lobe blood collections to determine the BLC.

According to Heck et al. (1985_a) a BLC difference of less than 1 mmol/l between the 10^{th} minute and the 30^{th} minute was the criteria to verify the existence of a blood lactate steady state during the test. The blood lactate steady state value was the mean BLC of the last four collections.

Lactate

Capillary blood samples (25ml) were taken from the hyperemic ear lobe (Finalgon, Thomae, Biberach, Germany) and immediately analysed using an enzymatic method (Yellow Springs Instruments 1500L-Sport analyser) to determine BLC.

Statistics

The data statistics are reported as mean values and standard deviations.

To study the lactate kinetics during the various stages of analysis during the 30min test, we used mean and standard deviation, mean upper and lower confidence interval (95%), as well as repeated measure Anova. The level of significance was set at 5%.

Results

The mean velocity corresponding to the V_4 obtained in the incremental step test was 3.93±0.28 m/s. Only 2 of the 13 subjects were not able to maintain a lactate steady state during the 30 min constant test (both finished the test at the 25^{th} minute stage with 9.82 and 7.25 mmol/l BLC, respectively). The remaining subjects supported the test with a mean steady state blood lactate value of 4.15±1.11 mmol/l in the last 20 min.

The descriptive data of individual mean values and standard deviation of V_4 and mean BLC of the last 20 minutes of the constant test are presented in Table 1.

Figure 1 – BLC during an incremental load step test; the test starts with 3,6m/s and the workload was increased every 5,30 minutes until an upper 4mmol/l BLC.

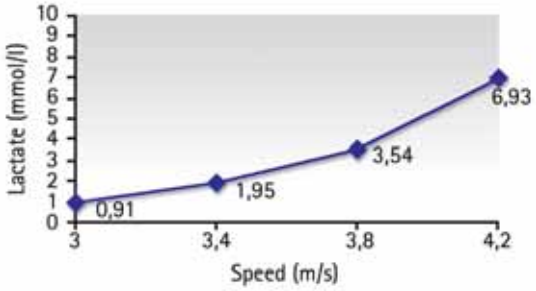
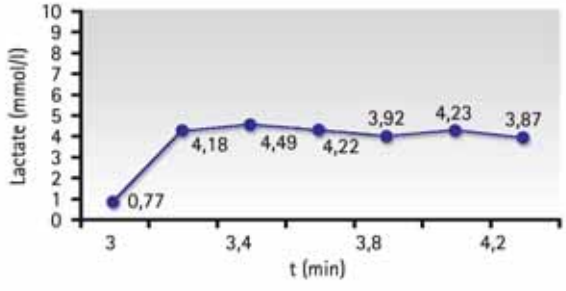


Figure 2 – BLC during a 30 minutes constant load test; the test is achieved at the velocity corresponding to the aerobic-anaerobic threshold, previously determined using an incremental load step test described in figure 1.



Subject	V_4 (m/s)	Mean BLC of the last 20 min constant load test (mmol/l)
A	3.9	3.76
B	4.1	5.18
C	4.4	3.82
D	3.9	4.06
E	3.5	3.00
F	3.5	2.77
G	4.1	4.88
H	4.1	3.12
I	4.1	3.97
J	3.8	4.58
K	3.8	6.62
L	4.4	9.18
M	3.9	6.63
Mean	**3.93**	**4.74**
SD	**0.31**	**1.81**

Table 1 – Individual mean values and standard deviation of V_4 and 30 minute constant test BLC.

Time (min)	5	10	15	20	25	30
nº of cases	13	13	13	13	13	11
Minimum	2.79	2.86	2.62	2.30	3.00	3.03
Maximum	6.25	7.74	8.99	8.72	9.82	6.74
Median	4.21	4.49	4.28	4.00	4.23	3.97
Mean	4.20	4.50	4.67	4.57	4.87	4.25
95% upper CI	4.83	5.31	5.73	5.66	6.06	5.00
95% lower CI	3.58	3.70	3.62	3.49	3.68	3.50

Table 2 – Descriptive statistic of BLC values (mmol/l) (mean, standard deviation, minimum, maximum, median, mean 95% upper and lower confidence interval (CI)) of the subjects during a 30-minute constant test.

The mean BLC for the different stages (5, 10, 15, 20, 25 and 30 minutes) of the constant test was respectively: 4.21, 4.50, 4.67, 4.57, 4.87 and 4.25 mmol/l. There were no significant differences in the repeated observations ($F(5,6) = 1.035$; $p = 0.474$), leading us to the conclusion that no evidence exists of intra-individual BLC differences during the 30 minute test.

Discussion

The major finding of this study was that 84.6% of the subjects were able to sustain a workload corresponding to V_4 during a prolonged period of time in a steady state BLC.

Aerobic capacity depends on the ability of the energy systems to metabolise substrates, such as blood glucose, liver and muscle glycogen, free fatty acids and triglycerides. The supplementary anaerobic energy production provided by glycolysis leads to lactate formation. As an end product of glycolysis, lactate is considered to be, like other metabolites, closely related to muscle fatigue (van Hall 2000). During continuous exercise a steady state BLC is required to sustain the V_4 workload intensity during a prolonged period of time.

The appearance of lactate in blood reflects the balance between the rate of production in muscle and its clearance. A number of authorities have identified factors which affect blood lactate concentration; these include fibre type composition (Donovan and Pagliassoltti 2000, Ivy et al. 1980), muscle respiratory capacity (Ivy et al. 1980), capillary density (Soares 1992, Tesch et al. 1981) and capillary/fibres ratio (Soares 1992). Two more are the favoured mobilisation of fats instead of carbohydrates as energy substrates at the same relative exercise intensity (Green 1996, Henriksson 1996 Holloszy 1996 Beneke et al. 2000, Ivy et al. 1980,) and finally, facilitated membrane transport (monocarboxylate protein transporters) from the cell to the circulation and to the mitochondria (Bonen 2000, Gladden $2000_{a,b,}$ Brooks 2000. Endurance training induces changes in all the factors mentioned above, which are related to the capacity for pyruvate oxidation and to the increased efficiency of the pathways leading to lactate oxidation, consumption and release (Brooks et al. 2000, Gladden $2000_{a,b}$).

The results of the present study indicate that, with the exception of two subjects, the V_4 is sustained in steady state BLC conditions. When the exercise intensity is close to the anaerobic threshold, BLC steady state during prolonged workloads is primarily related to the individual MaxLass (Foxdal et al. 1996).

An investigation conducted by Foxdal et al. (1996) demonstrated that the workload corresponding to OBLA 4mmol/l was not supported by 5 out of 6 marathon runners during a 50 minutes treadmill test (mean running duration: 30±6 min; mean BLC: 7.9±0.8 mmol/l). The subject who completed the 50 minutes run registered a BLC of 4.5 mmol/l. Thus, a V_4 re-test should be considered in order to confirm the aerobic-anaerobic threshold determination.

In contrast, the same study showed that 7 in 8 firemen completed the 50 minutes run with a mean steady state BLC of 5.3±0.6 mmol/l. However, one of the firemen finished the test with a BLC of 7 mmol/l. This suggests that individual MaxLass is a key factor to sustain a running intensity close to the anaerobic threshold for a prolonged period of time.

In the present study the mean BLC in the 30 minutes test was ~4 mmol/l, however the data showed a large inter-individual variation. Following the same criteria established by Heck et al. (1985_a), a BLC steady state was found during the test in 11 of the 13 subjects. This was confirmed by repeated measure analysis, demonstrating that there were no significant intra-individual differences among mean BLC values during the 30 min constant test. For those 2 subjects who did not finish the test, V_4 was eventually above the workload corresponding to MaxLass. So, they stopped the test with 9.92 and 7.25 mmol/l BLC. Indeed, in accordance with a recent study in young athletes (Santos and Ascensão 1999), the BLC corresponding to MaxLass was around 5 mmol/l, ranging from 2.78 to 7.12 mmol/l, which confirms the interindividual variability of the referred physiological parameter.

Aerobic capacity has been referred to as a factor that promotes the glycogen sparing effect (Brooks and Mercier 1994, Duncan and Howley 1999) and then influences the BLC during exercise. Besides the low endurance level of the subjects in our study (mean V_4 was 3.93 m/s) and also the large gap in endurance capacity (V_4 range was 3.5-4.4 m/s), the 30 minutes test was performed 3 days after the V_4 assessment. Thus, different steady state BLC could be expected during the 30 minutes test, eventually due to differences in the energetic pattern of substrate mobilisation and to different rates of glycogen repletion among subjects (Beneke et al. 2000). Indeed, Giesen et al. (1998) found a respiratory quotient of around 1.0 for an intensity corresponding to MaxLass, which confirms the relevance of glycogen as a key substrate during exercise at the referred load.

In conclusion, according to our data there were no significant intra-individual differences within subjects revealed by the numerous blood sample analyses taken during the 30 minutes test, and so, a blood lactate steady state during the 30 minutes constant load could be achieved at an intensity corresponding to aerobic-anaerobic threshold. ■

Contact:

A. Ascensão (✉) . P. Santos . J.Magalhães . JMC Soares
Department of Sports Biology
Faculty of Sport Sciences and Physical Education, University of Porto
Rua Dr. Plácido Costa, 91
4200-450 Porto, Portugal
e-mail: aascensao@fcdef.up.pt
Tel: 351-225074774 ;
Fax: 351-225500689

J. Oliveira
Department of Sports Training
Faculty of Sport Sciences and Physical Education, University of Porto
Rua Dr. Plácido Costa, 91
4200-450 Porto, Portugal

J. Maia
Department of Kinanthropometry and Applied Statistics
Faculty of Sport Sciences and Physical Education, University of Porto
Rua Dr. Plácido Costa, 91
4200-450 Porto, Portugal

References

Beneke, R., Hütler and Leithäuser (2000). Maximal lactate steady state independent of performance, Med. Sci. Sports Exerc. 32 (6): 1135-1139.

Beneke, R., Heck, H., Schwarz, V. and Leithäuser, R. (1996). Maximal lactate steady state during the second decade of age, Med. Sci. Sports Exerc. 28 (12): 1474-1478.

Beneke, R. and von Duvillard, S. (1996). Determination of maximal lactate steady state response in selected sports events, Med. Sci. Sports Exerc. 28 (2): 241-246.

Bonen, A. (2000). Lactate transporters (MCT proteins) in heart and skeletal muscles, Med. Sci. Sports Exerc. 32 (4): 778-789.

Brooks, G. (2000). Intra- and extra cellular lactate shuttles, Med. Sci. Sports Exerc. 32 (4): 790-799.

Brooks, G. (1986). Lactate production under fully aerobic conditions: the lactate shuttle during rest and exercise, Federation Proc. 45: 2924-2929.

Brooks, G. and Mercier, J. (1994). Balance of carbohydrate and lipid utilisation during exercise: the "crossover" concept, J. Appl. Physiol. 76 (6): 2253-61.

Donovan, C. and Pagliassotti, M. (2000). Quantitative assessment of pathways for lactate disposal in skeletal muscle fibre types, Med. Sci. Sports Exerc., 32 (4): 772-777.

Duncan, G. and Howley, E. (1999). Substrate metabolism during exercise in children and the "crossover concept", Ped. Exerc. Sci. 11: 12-21.

Föhrenbach, R., Mader, A. and Hollmann, W. (1987). Determination of endurance capacity and prediction of exercise intensities for training and competition in marathon runners, Int. J. Sports Med. 8 (1): 11-18.

Foxdal, P., Sjödin, B. and Sjödin, A. (1996). Comparison of blood lactate concentrations obtained during incremental and constant intensity exercise, Int. J. Sports Med., 17 (5): 360-365.

Giesen, H., Klee, D. and Mader, A. (1998). Relation between steady state lactate concentration and respiratory quotient during prolonged exercise of high intensity, Med. Sci. Sports Exerc. 30 (5): S245.

Gladden, B. (2000a). The role of skeletal muscle in lactate exchange during exercise: introduction, Med. Sci. Sports Exerc. 32 (4): 753-755.

Gladden, B. (2000b). Muscle as a consumer of lactate, Med. Sci. Sports Exerc. 32 (4): 764-771.

Green, H. (1996). What is the physiological significance of training –induced adaptations in muscle mitochondrial capacity? In Biochemistry of Exercise IX. R.J. Maughan and S.M. Shirreffs (Eds), Part I: pp. 3-12. Human Kinetics, Champaign, IL.

Hartmann, U. and Mader, A. (1994). Importance of lactate parameter for performance diagnosis and for the regulation in top competition and in recreational sports, J. Sports Med. Phys. Fitness 35 (1): 14-20.

Heck, H., Mader, A., Hess, G., Muller, R. and Hollman, W. (1985a). Justification oh the 4mmol/l lactate threshold, Int. J. Sports Med 6: 117-130.

Heck, H., Hess, G. and Mader, A. (1985b). Vergleichende Untersuchung zu Verschiedenen Laktat - Schwellenkonzepten - comparative study of different lactate threshold concepts, Deutsche Zeitschrift fur sportmedizin 2: 19-25.

Heck, H., Hess, G. and Mader, A. (1985c). Vergleichende Untersuchung zu Verschiedenen Laktat - Schwellenkonzepten - comparative study of different lactate threshold concepts, Deutsche Zeitschrift fur sportmedizin 2: 40 - 52.

Henrikson, J. (1996). Muscle adaptation to endurance training: impact on fuel selection during exercise. In Biochemistry of Exercise IX. R.J. Maughan and S.M. Shirreffs (Eds), Part I: pp. 329-338. Human Kinetics, Champaign, IL.

Holloszy, J. (1996). Regulation of carbohydrate metabolism during exercise: new insights and remaining puzzles. In Biochem-

istry of Exercise IX. R.J. Maughan and S.M. Shirreffs (Eds), Part I: pp. 3-12. Human Kinetics, Champaign, IL.

Ivy, J., Withers, R., Van Handel, P., Elger, D. and Costill, D. (1980). Muscle respiratory capacity and fibre type as determinants of the lactate threshold, J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 48 (3): 523-527.

Krüger, J.; Schnetter, S., Heck, H. and Hollmann, W. (1990). Relationship between rectangular - triangular increasing workload and maximal lactate steady-state on the crank ergometer, Elsevier Science Publishers B.V. (Biomedical Division) Sports Medicine and Health, G.P.H. Hermans editor: 685 - 690.

Mader, A., Liesen, H., Heck, H., Philippi, H., Rost, R., Schürch, P. and Hollmann, W. (1976). Zur Beurteilung det sportartspezifischen Ausdauerleistungsfähigkeit im Labot, Sportarzt Sportmed. 24 (4), 80 (5), 26 (5): 109.

Mader, A. (1991). Evaluation of endurance performance of marathon runners and theoretical analysis of test results, J. Sports Med. and Phys. Fitness 31 (1): 1-19.

Pianosi, P., Seargeant, L. and Haworth, J (1995). Blood lactate and pyruvate concentrations, and their ratio during exercise in healthy children: developmental perspective, Eur. J. Appl. Physiol. 71: 518-522.

Pfitsinger, P. and Freedson, P. (1997a). Blood lactate responses to exercise in children,: Part 1, Peak lactate concentration, Ped. Exerc. Sci. 9: 210 - 222.

Pfitsinger, P. and Freedson, P. (1997b). Blood lactate responses to exercise in children,: Part 2, Peak lactate concentration, Ped. Exerc. Sci. 9: 299 - 307.

Santos, P. and Ascensão, A. (1999). Maximal lactate steady state in young male athletes, in Abstract Book of Youth Sport in the 21th Century Congress, pp 67, Michigan State Univerity, Institute for the Study of Youth Sports, East Lansing, Michigan.

Soares (1992). Effects of raining on muscle capillary pattern: intermittent vs. continuous exercise, J. Sports Med. Phys Fitness 32: 123-127.

Tesch, P., Sharp, D. and Daniels, W. (1981). Influence of fibre type composition and capillary density on onset of blood lactate accumulation, Int. J. Sports Med. 2 (4): 252-255.

Van Hall, G. (2000). Lactate as a fuel of mitochondrial respiration, Acta Physiol. Scand. 168: 643-656.

Williams, J., Armstrong, N. and Kirby, B. (1990). The 4 mmol blood lactate level as an index of exercise performance in 11-13 year old children, J. Sport Sci. 8: 139-147.

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