THE APPLICATION OF CRITERION OBLA IN PRESCRIBING RUNNING ENDURANCE TRAINING INTENSITY IS LIMITED

Anton Ušaj

UPORABA KRITERIJA OBLA PRI DOLOČANJU INTENZIVNOSTI VZDRŽLJIVOSTNE VADBE PRI TEKU JE OMEJENA

Abstract

The criterion »onset of blood lactate accumulation« (OBLA) determined in an incremental testing protocol frequently corresponds to maximal lactate steady state phenomenon (maxLAss) during continuous exercise. The aim of this study was to ascertain whether the above-mentioned relationship between both phenomena exists also for intermittent running. Nine healthy runners participated in an incremental testing protocol of repeated 1200 m distances and a training session of 8 x 2000 m, repeated at increased velocities until they were unable to complete the entire session at the required running velocity. Results showed that vOBLA corresponded to maxLAss during training for seven of the runners, but at increased [LA] = 5.7±1.2 mmol/l, which is in contrast to LA_{OBLA} = 4 mmol/l. In contrast, for the two remaining runners, [LA] changed in an non–linear manner. Heart rate (HR) reached steady values of 171± 8 b/min, similar as HR_{OBLA}= 170±9 b/min. When the running velocity was increased to $v_{OBLA+0.2}$ m/s, a dramatic decrease in running distance occurred because of exhaustion. This phenomenon was accompanied by an increase in [LA]. In contrast to expectations, HR did not increase significantly (175 ± 7 b/min). It may be concluded that OBLA may represent a velocity corresponding to maxLAss for most subjects, however it failed to influence blood [LA] response during the test and training sufficiently, to be taken as similar and/or predictable. It seems that HR_{OBLA} cannot be used as a precise criterion for the determination of $HR_{maxLAss}$ during training, because it cannot differentiate between $v_{maxLAss}$ and higher velocity, which effects the early fatigue phenomenon. This means that the OBLA criterion may be a weak method for prescription of running intensity during endurance training.

Key words: testing, OBLA, endurance training, steady state

Izvleček

Kriteriju začetnega kopičenja laktata v krvi (OBLA), uporabljenem v večstopenjskem obremenilnem testu, pogostokrat ustreza najvišje stacionarno stanje vsebnosti laktata (maxLAss) pri neprekinjeni obremenitvi. Želeli smo ugotoviti ali se omenjena povezanost med obema pojavoma ohranja tudi pri uporabi metode s ponavljanji. Devet zdravih tekačev je opravilo dva testa: test ponovljenih tekov na 1200 m razdaljah in test - vadbo 8x2000 m s hitrostjo, ki se je v različnih testnih dneh spreminjala z namenom, da bi ugotovili tisto najvišjo hitrost, pri kateri tekač še zmore opraviti testiranje v celoti. Rezultati kažejo, da hitrost teka v_{OBLA} ustreza hitrosti, pri kateri se pojavi tudi maxLAss in sicer pri sedmih tekačih, toda pri povečani [LA] = 5.7 ± 1.2 mmol/l, kar je različno od vsebnosti, ki je podlaga za kriterij OBLA (4 mmol/l). Pri preostalih dveh tekačih se [LA] spreminja nelinearno. Frekvenca srca (HR) fluktuira stacionarno pri vrednostih 171 ± 8 u/min, podobno kot HR_{OBLA} = 170 ± 9 u/min. Povečanje hitrosti teka na $v_{OBLA+0.2}$ m/s je povzročilo zgodnejšo utrujenost, tako da nihče od tekačev ni zaključil testiranja. Omenjen pojav spremlja povečanje [LA]. Nasprotno pričakovanemu, pa se HR ne spremeni (175 ± 7 u/min). Lahko zaključimo, da kriterij OBLA lahko določa tisto hitrost teka, ki pri uporabi metode s ponavljanji sovpada s pojavom maxLAss pri večini preiskovancev, toda pri različni [LA], ki je ni mogoče predvideti. Zgleda, da HR, ki jo določa OBLA ne more biti dovolj natančen kazalec intenzivnosti teka, ki bi ločeval med intenzivnostjo, ki še ustreza najvišjemu stacionarnemu stanju za laktat in nekoliko višjo hitrostjo, ki povzroči zgodnjo utrujenost. To kaže na dokajšnjo omejenost pri uporabi kriterija OBLA pri vzdržljivostni vadbi.

Ključne besede: testiranje, OBLA, vzdržljivostna vadba, stacionarno stanje

University of Ljubljana – Faculty of Sport, Ljubljana, Slovenia

Contact address
Anton Ušaj
Univerza v Ljubljani, Fakulteta za šport, Gortanova 22, SI-1000 Ljubljana, Slovenija

Tel: +386 1 540-10-77
Fax: +386 1 540-22-33
E-mail: anton.usaj@sp.uni-lj.si

INTRODUCTION

An adequate method for prescribing endurance training intensity has been searched for intensely for several decades. The basic approach adopted in most studies was to determine a certain characteristic running velocity and/or heart rate (HR) with the use of an incremental exercise testing protocol and apply it in endurance training as the appropriate intensity (Coen, Schwary, Urhausen, and Kindermann, 1991; Fahrenbach, Mader, and Hollman, 1987; Gilman and Wells 1993; Jannsen 1987; Kindermann, Simon and Keul, 1985; Yoshida, 1984). When the Lactate Threshold (LT), Individual Anaerobic Threshold (IAT) and Onset of Blood Lactate Accumulation (OBLA) were defined, and a high correlation was observed between the corresponding running velocities and the running velocities achieved in endurance running events (Farrel, Wilmore, Coyle, Billing and Costill, 1979; Kiayoji and Matsuura, 1984; Kindermann, Simon and Keul, 1985; Usaj and Starc, 1996; Yoshida, 1984), these criteria became intensely researched with a view to their practical application in endurance running training. The greatest attention was devoted to [LA] analysis (Kindermann, Simon and Keul, 1985; Mognoni, Sirtori, Lorenzelli and Cerretelli, 1990; Orok, Hugson, Green and Thomson, 1989; Oyono-Enguelle et al, 1990), which was sometimes complemented also with analysis of HR (Gilman and Wells, 1993; Katch, Weltman, Sady and Freedsom, 1979) and $\dot{V}o_2$ (Oyono-Enguelle et al, 1990). The results from these studies led to two opposite conclusions. One group of studies supported the use of IAT and/or OBLA for determining endurance training intensity. This conclusion was based on results showing that running intensities corresponding to OBLA and IAT induced the maximal lactate steady state (maxLAss) during continuous exercise (Fahrenbach, Mader and Hollman, 1987; Kindermann, Simon and Keul, 1985; Schnabel, Kindermann, Schmitt, Biro and Stegeman, 1982; Stegeman and Kindermann, 1982; Urhausen, Coen, Weiler and Kindermann, 1993). The maxLAss level is considered an important limit for prolonged exercise (Kindermann, Simon and Keul, 1985; Stegeman and Kindermann, 1982; Urhausen, Coen, Weiler and Kindermann, 1993, Usaj and Starc, 1996). The above results were contradicted by studies showing [LA] values other than 4 mmol/l in individual subjects and/or non-steady-state fluctuations in [LA] during prolonged exercise at an intensity corresponding to OBLA (Mognoni, Sirtori, Lorenzelli and Cerretelli, 1990; Orok, Hugson, Green and Thomson, 1989; Oyono-Enguelle, Heitz, Marbach, Ott, Gartner, Pope and Vollmer, 1990). It seems that under certain testing and training conditions, the philosophy of training prescription may be valid for predicting maxLAss, which means that testing characteristics such as the duration of individual stages and the increase in exercise intensity per stage should be carefully selected and approved in advance. On the other hand, it is difficult to believe that a certain intensity determined during an incremental test represents a general steady state of the physiological response. Under testing conditions the intensity increases stepwise, whereas during a training session an abrupt increase occurs in the initial phase. Therefore, other physiological characteristics, which are regulated differently than [LA], may not show steady-state fluctuations during such exercise. The first aim of the study was to ascertain whether the [LA] determined by criterion OBLA during incremental testing protocol reflects similar [LA]= 4 mmol/l values and the maxLAss phenomenon also during intermittent exercise of 8 x 2000 m with 1 min breaks, when the velocity corresponds to v_{OBLA}. Since the introduction of heart rate (HR) monitors into everyday training practice, their use for the control of endurance training intensity has been advocated (Jannsen, 1987). Therefore, the second aim of the study was to ascertain if HR_{OBLA} corresponds to steady HR at the level of maxLAss during training.

METHODS

Subjects.
Nine healthy runners (age: 25±5 years; height: 175±5 cm; mass: 69±8 kg) participated voluntarily in the study after giving a written informed consent approved by the National Ethics Committee. All the subjects were marathon runners who ranged in endurance performance from the international level (2:13 h marathon) to the recreational level (3:30 h marathon).

Testing protocol
The testing protocol consisted of a sequence of 1200 m runs at increasing running velocity. The number of runs depended on the selection of the initial velocity and on the runners' endurance. The initial running velocity was selected so as to increase the heart rate (HR) to 100 b/min. The velocity was then increased in each successive run by 0.2 m/s, ending with the highest running velocity possible for the described protocol. The runs were interrupted by breaks of up to 70 s for blood sampling. The running velocity was controlled by sound signals played back on a tape player (Walkman). The signals were separated by time intervals equivalent to running a 50 m distance at a particular velocity.

A training session consisted of a sequence of 8 runs of 2000 m performed at a constant velocity. On the first training day, the velocity corresponded to V_{OBLA} determined in the testing protocol. On each further training day, the running velocity was increased by 0.2 m/s until the runner could not complete the session because of fatigue. If a runner was unable to run at v_{OBLA} on the first training day, the velocity was reduced by 0.2 m/s on the following training days until steady values of LA were reached.

Blood collection, biochemical and heart rate measurements

Capillary blood samples (20 µl) were collected after each run from a hyperemizied ear lobe for [LA] analysis using an Analox GM7 (Analox, England) instrument. The heart rate (HR) was monitored continuously using a PE3000 Pulse Meter (Polar Electro, Finland).

Data processing and analysis

For the OBLA (Onset of Blood Lactate Accumulation) criterion a [LA] value of 4 mmol/l was applied (Karlsson and Jacobs, 1982) by using the method described first by Beaver et al (Beaver, Wasserman and Whipp, 1986; Usaj and Starc, 1993; Usaj and Starc; 1996). The corresponding velocity was denoted as v_{OBLA} and the corresponding HR as HR_{OBLA}. Data from the training sessions was used to determine the [LA] steady state (LAss). The linear interpolation model of the [LA] changes was chosen:

$$LA_x = LA_1 + b * x \qquad \text{(Equation 1)},$$

where LA_x was the [LA] value calculated at distance x and LA_1 was the [LA] value obtained after the third run, b was the slope coefficient. The running velocity (v_{LAss}), and [LA] (LA_{LAss}) were calculated. [LA] was considered steady when its change from the third to the last 2000 m run (Δ[LA]/Δx) did not exceed 0.5 mmol/l (0.05 mmol/l/km).

The average HR, calculated from the last 10 values measured during the training sessions (saved in pulse meter memory every 5 s), were used as a representative HR of a certain 2000 m run. These average values were further used for comparisons between testing and training conditions. Additionally, a linear interpolation model is used to determine HR steady state:

$$HR_x = HR_1 + c * x \qquad \text{(Equation 2)},$$

where HR_x was the HR calculated at distance x and HR1 was the HR obtained after the third run; e was the slope coefficient. HR was considered steady when its change from the third to the last 2000 m run (ΔHR/Δx) did not exceed 10 b/min (1 b/min/km).

Statistics

The values were represented as means ± standard deviations (SD). The paired t-test was used to compare the data for LA and HR from the testing protocols and the training sessions. A significance level of 0.05 was selected. Correlations between the selected variables were calculated using the Pearson correlation coefficients. All statistical parameters were calculated using the graphical statistics packages Sigma Stat and Sigma Plot (Jandel, Germany).

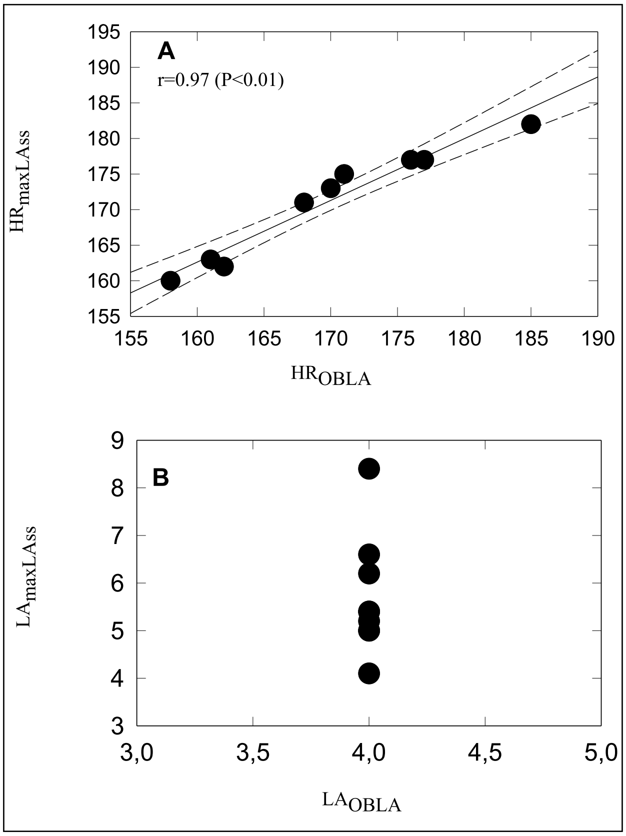
RESULTS

The velocity determined with the OBLA criterion (v_{OBLA}) was 4.60 ± 0.43 m/s and the corresponding heart rate (HR_{OBLA}) was 170 ± 9 b/min.

When v_{OBLA} was used during training, all the subjects were able to complete the whole 8x2000 m session (Fig. 1). For 7 subjects, [LA] increased during the initial phase of training and then fluctuated near the steady values. Two of these subjects reached steady [LA] values, as demonstrated by the zero slopes of the interpolation lines (Fig. 2A). The remaining five subjects showed a very gentle increase in [LA] of less than 0.5 mmol/l from the distance of 4 to 16 km, which was assessed as steady fluctuations. For the subject, whose initial [LA] increase was the lowest in the group, [LA] later continued to increase, exhibiting non-steady fluctuations (Fig 2A). For the remaining 2 subjects, non–steady state fluctuations of [LA] occurred. The arithmetic mean of whole group demonstrated steady-state values of about 5.7 ± 1.2 mmol/l throughout the training session (Fig. 1A). The heart rate increased during the first and second 2000 m runs. Thereafter it reached steady values of 171 ± 8 b/min (Fig. 2B).

To ascertain if the steady level of [LA] might correspond to the maximal [LA] steady state at v_{OBLA}, all the subjects repeated the training at v_{OBLA} + 0.2 m/s ($v_{OBLA+0.2}$). The results showed that [LA] increased beyond the level of maxLAss for 5 subjects, and for 2 others, where the increase in [LA] was very slow, was close to the steady state. All the subjects, except one, stopped running after less than 8 km because of exhaustion (Fig. 2A and 2B). Heart rate increased during the first 2000 m run, reaching similar steady values as at v_{OBLA} (172 ± 6 b/min); no significant further increase in HR was observed during the second and third run (175±7 and 173±8 b/min) (Fig. 2B).

To ascertain whether the response of [LA] and HR during the test and training were compatible at similar running velocities (v_{OBLA} and vmaxLAss), the correlations between observed results were calculated. The correlation between HR_{OBLA} and $HR_{maxLAss}$ is very strong (r= 0.97; P<0.01) (Fig. 2A). On the contrary,



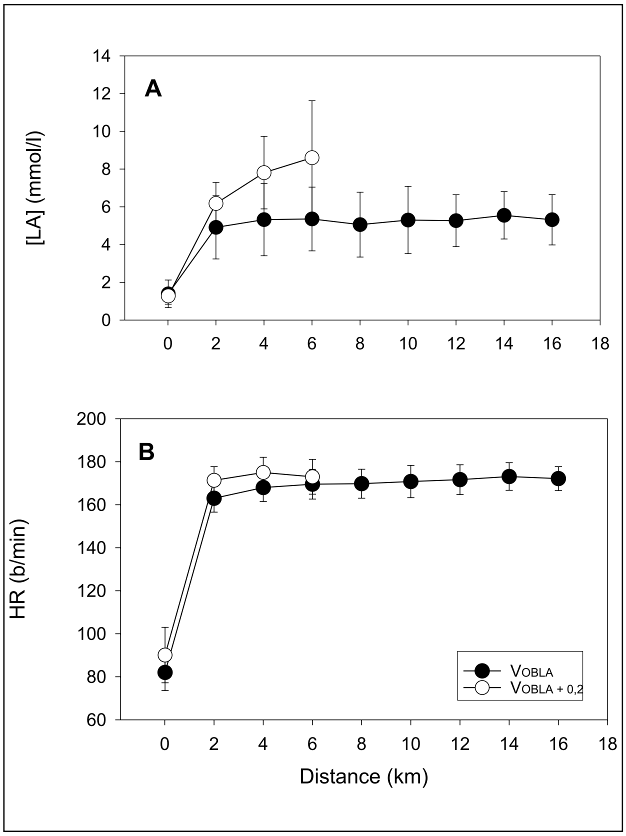


Figure 1

Group changes (mean ± SD) in [LA] – (A) and HR – (B), during a sequence of eight 2 km runs using v_{OBLA} (black circles) and $v_{OBLA+0.2\ m/s}$ (white circles). The steady state fluctuations in [LA] corresponded to those in HR. When the velocity exceeded the maxLAss level, [LA] continued to increase, in contrast to HR, which remained steady.

Figure 2

HR_{OBLA} and $HR_{maxLAss}$ correlated significantly (A), when v_{OBLA} was used during a sequence of eight 2 km runs. A similar correlation for LA (B) was not observed.

the correlation between LA_{OBLA} and $LA_{maxLAss}$ did not exist, because first criterion used fixed [LA] = 4 mmol/l in contrast to very different $LA_{maxLAss}$ (Fig. 2B).

DISCUSSION

The results of this study lead to the following conclusions:

1. The running velocity v_{OBLA} determined in the incremental test may influence the maximal [LA] steady state, when it is repeated in intermittent running training sequence consisting of relatively long runs (≈ 2 km) and short breaks (≈ 1 min).
2. The phenomenon maxLAss showed very different, individually dependent, $LA_{maxLAss}$ which did not reflect [LA] = 4 mmol/l, characteristic for OBLA.
3. Heart rate observed during $v_{maxLAss}$ did not differ from that observed during 0.2 m/s higher velocity than v_{OBLA}, which induced earlier fatigue.

All the subjects completed the training session at velocities corresponding to $v_{maxLAss}$, which was similar to v_{OBLA}. When the velocity was increased by 0.2 m/s and [LA] fluctuations exceeded the steady conditions, fatigue occurred earlier, somewhere between the distance of 4 and 8 km. The concentration of lactate in blood ([LA]) depends on its production, as well as the rate of its appearance in the blood and on its disappearance from the blood. Lactate is produced by glycolysis. It is decomposed mainly by aerobic processes in the less-intensely exercised muscles of the upper body; as well as the arms, heart and liver. When the rate of its appearance in blood is equal to the rate of its disappearance, the [LA] steady state (LAss) will occur. The specific maximal level of LAss (maxLAss) is the most important variable because it limits the hypothetical range of LAss and represents the level of endurance performance (Urhausen et al., 1993; Usaj and Starc, 1996). It has been experimentally observed that under certain testing conditions, maxLAss may be predicted also from data obtained in an incremental testing protocol (Olbrecht et al., 1985; Urhausen et al., 1993). The criterions OBLA and IAT (Olbrecht et al., 1985; Urhausen et al., 1993) have been defined as adequate criteria, which determine exercise intensity corresponding to maxLAss. Our results support these findings, but only to a certain extent. Two of our subjects did not reach LAss. Therefore our results support also opposite findings, which did not find LAss if v_{OBLA} was repeated during continuous exercise (Mognoni et al., 1990; Orok et al., 1989; Oyono-Enguelle et al., 1990). It seems very difficult to define such testing conditions and criteria, which would guarantee accurate prediction of maxLAss. In addition, our results showed that HR values were steady at v_{OBLA} throughout the training session. All the subjects were able to complete the training session.

The HR fluctuations did not show a significant increase, nor a continuous increase of HR at v_{OBLA} + 0.2 m/s. These results were unexpected and surprising. They lead to the following conclusion: if HR_{OBLA} is used as the criterion of running intensity, then the running velocity need not correspond to $v_{maxLAss}$ but may be higher or lower.

The results of our study demonstrate that v_{OBLA} may be used as a very approximate criteria for the prescription of endurance training velocity. Velocity v_{OBLA} frequently corresponds to maxLAss under specific testing and training conditions. The very different [LA] values during training, which were not similar to 4 mmol/l, demonstrated that lactate kinetics was different than in test. In addition, HR_{OBLA} maintained during training, may influence velocity to be similar to $v_{maxLAss}$, if certain types of endurance training are used. However, it may also fail to reach $v_{maxLAss}$ intensity. Therefore mistakes would be frequent in any case. These findings offer only vague support to the hypothesis that the physiological response observed during testing can occur also during training if a similar intensity is used. Available literature shows that only certain criteria, such as the individual anaerobic threshold, may under specific testing conditions preserve [LA] at the maximal steady state during 30 minutes of exercise on a rowing ergometer (Urhausen et al., 1993), or a cycling ergometer, or during a 30-minute run (Stegeman and Kindermann, 1982). In one study, however, the same criterion applied under very similar conditions showed absence of correlation between the [LA] responses obtained during testing and during continuous exercise (Oyono-Enguelle et al., 1990). The aerobic-anaerobic threshold (Kindermann et al., 1985) showed that [LA] slowly but continuously increased (insignificant during 30 min exercise) to the level of 4 mmol/l. Others reported a very different response if Anaerobic Threshold (fixed 4 mmol/l [LA] criterion) intensity is performed during continuous exercise (Schnabel et al., 1982; Yoshida and Suda, 1982). The time course of [LA] during continuous exercise of different intensities displays specific characteristics, which conform to four typical patterns: a) initial [LA] increase followed by a decrease towards resting levels; b) fluctuations at the steady state level, after an initial increase if intensity is above that determined with the use of LT, but not above maxLAss; c) similar to b) but with an additional increase in the last period of exercise (after about 40 min); d) initial [LA] increase, followed by further continuous increase (Oyono-Enguelle et al., 1990). When LT is used as the criterion, the training intensity may be too low (Schnabel et al., 1982), except perhaps for very long running distances. Any changes in testing characteristics, especially in the duration of runs, may cause significant differences in v_{OBLA} but not in HR_{OBLA} (Usaj and Starc, 1993). In spite of that, HR_{OBLA} seems not be an accurate predictor of $HR_{maxLAss}$.

It may be possible to use v_{OBLA}, but not HR_{OBLA}, for an approximate prescription of endurance training, provided that continuous or maybe certain intermittent methods are employed. Several other methods are available for endurance training in the form of running. Three of them differ clearly among themselves. The continuous method uses continuous long and/or extra long runs, with intensity significantly below the individual maximal aerobic power ($\dot{V}_{O2\ max}$). Running intensity corresponding to the Lactate Threshold (LT), determined by testing, is believed to represent the proper intensity limit in this method (Coen et al., 1991; Fahrenbach et al., 1987; Jannsen, 1987; Kindermann et al., 1985; Lehman et al., 1985; Weltman, 1995). The intermittent method is characterised by a higher intensity but shorter duration of running, which is repeated several times with relatively long breaks. The training intensity usually exceeds the level of the maximal aerobic power, the velocity being significantly above LT. Lactate accumulates during running, but its concentration decreases during breaks, reaching steady or slowly increasing levels, which do not give rise to a dramatic sensation of fatigue. The interval method – extensive or intensive – represents a typical aerobic-anaerobic exercise in terms of how active the energy processes are. Compared to the other two methods, it involves a higher velocity, which is made possible by shorter running distances and frequent breaks. This results in faster lactate accumulation. Each of the described methods effectively increases endurance for the specific type of running training used. Since the training characteristics, such as the duration and intensity of running, duration of breaks, number of repetitions, etc., differ considerably, the question arises, whether the presented idea and practice of prescribing endurance training intensity may be applied to all endurance training methods. From our results, which demonstrated problems valid for a certain type of intermittent running, it may be suggested that this is not possible.

In conclusion, the criterion OBLA may represent velocity corresponding to maxLAss for most of the subjects, however it failed to influence blood [LA] response during test and training to be similar and/or predictable. It seems that HR_{OBLA} cannot be used as a precise criterion for determination of $HR_{maxLAss}$ during training, because it cannot differentiate between $v_{maxLAss}$ and higher velocity, which effects the early fatigue phenomenon. This means that the OBLA criterion may be a weak method for prescribing running intensity during endurance training, especially when applied in different methods.

REFERENCES

1. Beaver, W.L., Wasserman, K., & Whipp, B. (1986). Improved detection of lactate threshold during exercise using a log-log transformation. *J Appl Physiol, 60,* 472–478.
2. Coen, B., Schwary, L., Urhausen, A., & Kindermann, W. (1991). Control of training in middle- and long- distance running by means of the individual anaerobic threshold. *Int J Sports Med, 12,* 519–524.
3. Fahrenbach, R., Mader, A., & Hollman, W. (1987). Determination of endurance capacity and prediction of exercise intensities for training and competition in marathon runners. *Int J Sports Med, 8,* 11–18.
4. Farrel, P., Wilmore, J.H., Coyle, E.F., Billing, J.E., & Costill, D.L. (1979). Plasma lactate accumulation and distance running performance. *Med Sci Sports Exerc, 11,* 338–344.
5. Gilman, M.B., & Wells, C.L. (1993). The use of heart rates to monitor exercise intensity in relation to metabolic variables. *Int J Sports Med, 14,* 339–344.
6. Jannsen, P.G.J.M. (1987). *Training, lactate, pulse rate.* Oulu, Polar Electro Oy.
7. Karlsson, J., & Jacobs, I. (1982). Onset of blood lactate accumulation during muscular exercise as a threshold concept. *Int J Sports Med, 3,* 190–192.
8. Katch, V., Weltman, A., Sady, S., & Freedsom, P. (1979). Validity of the relative percent concept for equating training intensity. *Eur J Appl Physiol, 39,* 219–227.
9. Kiayoji, T., & Matsuura, Y. (1984). Marathon performance, anaerobic threshold and onset of blood lactate accumulation. *J Appl Physiol, 57,* 640–643.
10. Kindermann, W., Simon, G., & Keul, J. (1985). The significance of the aerobic – anaerobic transition for the determination of work load intensities during endurance training. *Europ J Appl Physiol, 54,* 84–88.
11. Lehmann, M., Berg, A., Kappi, R., Wessinhage, T., & Keul, J. (1983). Correlations between laboratory testing and distance running performance in marathoners of similar performance ability. *Int J Sports Med, 4,* 226–230.
12. Lehman, M., Schmid, P., & Keul, J. (1985). Plasma cathecolamine and blood lactate accumulation during incremental exhaustive exercise. *Int J Sports Med, 6,* 78–81.
13. Mognoni, P., Sirtori, M.D., Lorenzelli, F., & Cerretelli, P. (1990). Physiological responses during prolonged exercise at the power output corresponded to the blood lactate threshold. *Europ J Appl Physiol, 60,* 239–243.
14. Olbrecht, J., Madsen, O., Mader, A., Liesen, H., & Hollmann, W. (1985).Relationship between swimming velocity and lactic acid concentration during continuous and intemittent training exercise. *Int J Sports Med, 6,* 74–77.
15. Orok, C.J., Hugson, R.L., Green, H.J., & Thomson, J.A. (1989). Blood lactate responses in incremental exercise as predictors of constant load performance. *Europ J Appl Physiol,* 59, 262–267.
16. Oyono-Enguelle, S., Heitz, A., Marbach, J., Ott, C., Gartner, M., Pope, A., & Vollmer, J.C. (1990). Blood lactate during constant-load exercise at aerobic and anaerobic thresholds. *Europ J Appl Physiol, 60,* 321–330.
17. Schnabel, A., Kindermann, W., Schmitt, W.M., Biro, G., & Stegeman, H. (1982). Hormonal and metabolic consequences of prolonged running at the individual anaerobic threshold. *Int J Sports Med, 3,* 163–168.
18. Stegeman, H., & Kindermann, W. (1982). Comparison of prolonged exercise tests at the individual anaerobic threshold and the fixed anaerobic threshold of 4 mmol/l lactate. *Int J Sports Med, 3,* 105–110.
19. Urhausen, A., Coen, B., Weiler, D., & Kindermann, W. (1993). Individual anaerobic threshold and maximum lactate steady state. *Int J Sports Med, 14,* 134–139.
20. Usaj, A., & Starc, V. (1993). Exercise testing time affects blood lactate, pH and heart rate curves at discontinuous running tests. *Med Sci Sports Exerc, 25,* 5, S159 (abstract)
21. Usaj, A., & Starc, V. (1996). Blood pH and lactate kinetics in the assessment of running endurance. *Int J Sports Med, 17,* 34–40.
22. Weltman, A. (1995). *The blood lactate response to exercise.* Champaign: Human kinetics.
23. Yoshida, T. (1984). Effect of exercise duration during incremental exercise on the determination of anaerobic threshold and the onset of blood lactate accumulation. *Europ J Appl Phy, 53,* 196–199.
24. Yoshida, T., Suda, Y., & Takeuchi, N. (1982). Endurance training regimen based upon arterial blood lactate: Effects on anaerobic threshold. *Europ J Appl Phy,* 49, 223–230.