RELATIONASHIP BETWEEN ANAEROBIC TRESHOLD AND ENDURANCE PERFORMANCE IN SWIMMING EXPRESSED BY EVOLUTION OF LACTATE CONCENTRATION IN BLOOD AFTER FRANCAUX MODEL

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abstract: In a previous paper we studied by reflectance photometry lactic acid concentration during high performance swimmers training at different targets. In this work we try to explain this evolution using Francaux model to explore this data.

Introduction

It is known the essential role of lactic acids derivatives in organisms as metabolism products, fuel for sustaining of physical effort and vector of different drugs.

The basic biological foundations of performance diagnostics and of training guidance are the modes of energy provision for muscle contraction [1]:

1. The aerobic mechanism;
2. The lactic acid mechanism;
3. The alactic mechanism.

Energy is provided by all three mechanisms in specific proportions, depending on the intensity and duration of the exercise. Each individual mechanism operates according to its own laws. The three mechanisms differ in their capacity their output, the minimum time required for recovery after loading: for creatine phosphate to be built back up again, for lactate to be degraded and for muscle glycogen to be built up.

The time required for recovery ranges from seconds to minutes for creatine phosphate resynthesis, runs to several minutes for lactate degradation, and in the case of heavy cumulative exercise, may be long as a few days for restoration of muscle glycogen. The maximum possible performance decreases from the alactic mechanism, to the lactic acid and then the aerobic. For capacity the reverse order applies.

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The characteristics of motricity such as frequency and force impulse per movement cycle affect the degree to which the three mechanisms are used. The fundamental aim for any health oriented sporting activity is that working muscles should receive sufficient oxygen, ensuring that the energy produced comes almost exclusively from the oxygen – dependent aerobic break – down of carbohydrates and fats.

In a previous paper [1] we have studied blood lactic acid concentration during high performance swimmer training at different targets. The determinations of lactate concentration were effected with Accusport analyzer in field conditions [2].

In basic literature the strong relationship existing between the anaerobic threshold and the endurance performance of a subject is well documented [3÷5].

Anaerobic threshold is defined as the level of oxygen uptake (VO_2) at which a metabolic acidosis occurs. It may be determined by the point where the blood lactate concentration ($[La^-]$) begins to increase above its rest level during an incremental exercise test [6,7].

Similar concepts have been also developed using constant values (2 and 4 mmol/l) of the blood lactate concentration to determine the OBLA (Onset of Blood Lactate Accumulation) [8], the area of aerobic-anaerobic transition [9] or anaerobic threshold.

Beaver [10] have proposed a simple mathematical model to estimate the lactate threshold that require the transformation to logarithmic coordinates of each value of oxygen uptake and of $[La^-]$ to determine a threshold visually apparent.

All this models give satisfactory fit of the typical $[La^-]$ - VO_2 curve (see Fig. 1) but remain empirical.
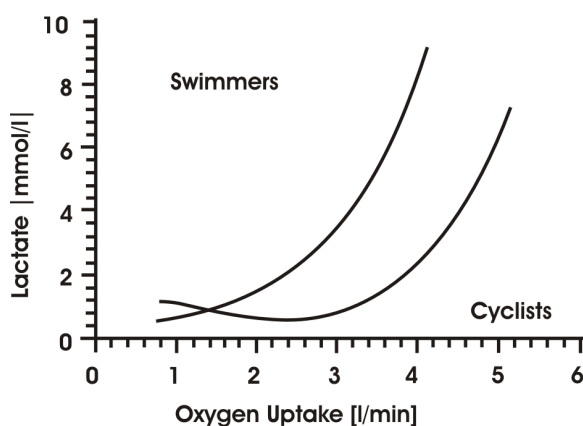

Fig. 1: *Mean evolution of blood lactate concentration in top level swimmers (n=5) and cyclists (n=5) during an incremental bicycle ergometer test.*

In 1993 Francaux et al [11] have published a mathematical model that describes evolution of $[La^-]$ versus VO_2 during an incremental exercise test. Deduction of final equation was based on demonstrated physiological phenomena.

During a continuous graded interval test, there is a linear relationship between time (t) and oxygen uptake (VO_2) at the end of each step and the equation that describes the evolution of blood lactate concentration versus VO_2, after Francaux, is:

$$\left[La^- \right] = \frac{P}{\alpha} e^{\alpha \cdot VO_2} - V_{max} \left\{ (K_M + VO_2) - \left[K_M \ln (K_M + VO_2) \right] \right\}, \tag{1}$$

where: P – is intercept; α – is the slope of exponential function that corresponds to rate of appearance of lactate in blood; V_{max} – is maximal rate of lactate elimination; K_M – constant of Michaelis – Menten (the VO_2 necessary to reach half of V_{max}).

Materials and Methods

The biometrical data (age, weight, height) of our swimmers mentioned in our precedent work [1] are disposed in the same range of values as the groups of the swimmers and cyclists tested in Francaux experiment [11] and have similar sportive performances (members of Olympic Team). Although, we can transfer/use some of established parameter for by Francaux protocol theoretical computation of lactate concentration evolution in our assisted swimming training. (This protocol was a continuous graded 3 minutes interval exercise test on an electrically braked bicycle Jaeger ergometer. This exercise started at a power output of 70 W, which was increased by 40 W every 3 minutes until voluntary cessation. At the end of each intensity level 25 µl of capillary blood were taken from the earlobe to determine lactate concentration with YSI lactate analyzer. Oxygen uptake was measured every 30 seconds using an Ergo-Oxyscreen Jaeger spirometer. A Sportester PE 3000 continuously recorded heart rate.)

Discussion

On this basis we extracted from [11] considered parameters from Table 1:

Table 1. Comparison between swimmers and cyclists after [11].

Parameters	Swimmers	Cyclists	F value	Prob > F
PWC 170 [beats/min]	279.4 ± 56.924	357.6 ± 19.604	8.436	0.0198
VO_{2peak} [l x min^{-1}]	4.096 ± 0.751	5.128 ± 0.352	7.741	0.0238
P [mmol x min x l$_{O2}^{-1}$ x l$_{Vd}^{-1}$]	0.423 ± 0.120	0.293 ± 0.032	5.383	0.0489
α [min x l$_{O2}^{-1}$]	0.767 ± 0.094	0.690 ± 0.067	2.184	N.S.
Vmax [mmol x min x l$_{O2}^{-1}$ x l$_{vd}^{-1}$]	1.850 ± 0.815	3.428 ± 0.959	7.861	0.0231
K_M [l$_{O2}^{-1}$ x min^{-1}]	2.591 ± 0.261	2.919 ± 0.070	7.405	0.0262

The PWC 170 is the power capacity for a 170 beats/min heart rate, which has been calculated from regression equation computed between the power output, and the heart rate between 100 and 180 beats/min.

VO_2 peak is definite as the peak of oxygen uptake measured during exercise.

We have computed theoretical [La] - VO_2 curve (Table 2) corresponding to our experimental data [1] after this model (Fig. 2).

Table 2. Calculated data after Francaux model.

Crt. no.	[La] mmol/l	VO$_2$ L/min
1	0.6416	0.925
2	0.6530	0.950
3	0.6734	1.000
4	0.9230	1.500
5	1.3624*	2.000
6	2.1402	2.500
7	3.3840*	3.000
8	5.4938*	3.500
9	6.9015	3.750
10	7.0198	3.800
11	7.9241	3.900
12	8.6915*	4.000

The values of calculated lactate concentrations nearly of those determinated in our precedent work [1] in different swimming conditions are marked with asterisk.
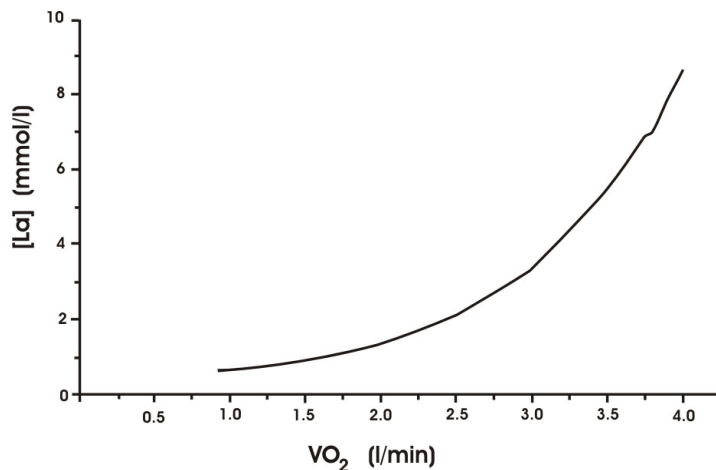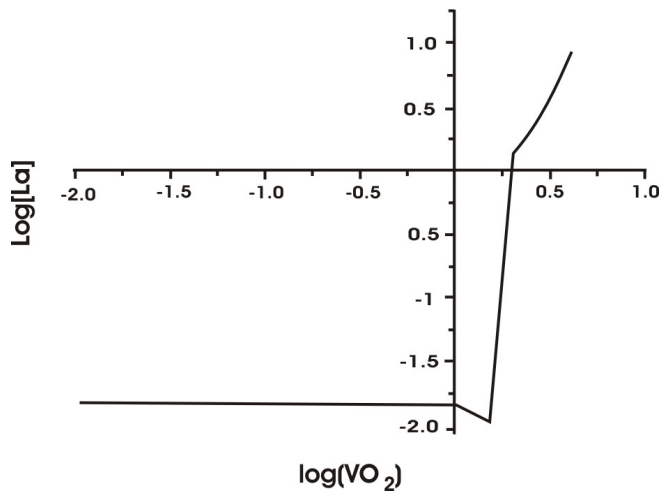

Fig. 2: *Calculated [La] – VO$_2$ curve.*

It is obvious that the value of VO$_2$ uptake corresponding to 3 l/min leads to a calculate concentration of blood lactate of 3.38 mmol/l which coincids satisfactory with that of 3.3 mmol/l, determined in our first training exercise [1] at 30 seconds break-time after each hundred meters of swimming. The values of VO$_2$ uptake larger than 3.5 l/min correspond to range of lactate concentration which surpasses the value of 4.0 mmol/l (considered as value for the performance at the „anaerobic threshold conditions") [1].

In Table 3 and Fig. 3 are presented the calculated data after Beaver [10] conditions which also sustained our previous observations about anaerobic threshold.

Table 3. Logarithmic values of Table 2 data.

Crt. no.	Log [La]	Log (VO_2)
1	−1.806	−1.965
2	−1.813	−1.977
3	−1.829	0
4	−1.965	0.176
5	0.134	0.301
6	0.330	0.397
7	0.528	0.477
8	0.739	0.546
9	0.844	0.574
10	0.845	0.579
11	0.898	0.591
12	0.939	0.602

Fig. 3: *Log [La] – log VO₂ curve.*

Concerning the values of calculated lactate concentrations which are nearly those determinated in training conditions of our previous work [1] is possible to observe appearence of larger lactate concentrations in plasma when distances target in swimming are to much fragmented. This also reflects regression of ability to effort adaptation of the swimmer in these conditions of training.

Conclusions

1. Use of Francaux model (in which the equation (1) is demonstrated on the physiological basis and no arbitrary selected) to calculate lactate concentration in

blood as function of VO_2 uptake shows a good fit of experimental typical curve for swimmers training.

2. In the serie of corresponding values [La] – VO_2 we can observe the *range of transition* (between 2-4 mmol/l lactate) and *anaerobic threshold* (at 4 mmol/l).

3. Analysis of calculated [La] concentrations in blood permits a logical mode of training which exclude too much fragmentation of target distance in swimming.

REFERENCES

1. Bratu, I.G., Badescu, V. and Mandravel, C. (2001) *RICCCE* **12**, 242-47.

2. Pansold, B. (1999) *Workshop report Accusport* **18**, Zürich, 9-17.

3. Farrell, P.A., Wilmore, J.H., Coyle, E.F., Billing, J.E. and Costill, D.L. (1979) *Med. Sci. Sports.* **11**, 338-44.

4. Li, L., Stratman, F.W. and Lardy, H.A. (1986) *FEBBS Lett.* **208**, 297-300.

5. Tanaka, K., Matsuura, Y., Kumagai, S., Matsuzaka, A., Hirakoba, K. and Asano, K. (1983) *Eur. J. Appl. Physiol.* **52**, 51-6.

6. Yoshida, T. (1993) *Eur. J. Appl. Physiol*. **53**, 196-9.

7.   Francaux, M.A., Jacqmin, P.A. and Sturbois, X.G. (1993) *Arch. Int. Physiol. Bioch. Bioph*. **101**, 57-61.

8. Jacobs, I. (1981) *Acta Physiol. Scand*., Suppl., 495.

9. Kindermann, W., Simon, G. and Keul, J. (1979) *Eur. J. Appl. Physiol*. 42, 25-34.

10. Beaver, W.L., Wasserman, K. and Whipp, B. (1985) *J. Appl.Physiol.* **59**(6), 1936-40.

11. Francaux, M.A., Jacqmin, P.A. and Sturbois, X.G. (1993) *Arch. Int. Physiol. Bioch. Biop.* **101**, 303-9.

12. Vigneron, H. (1931) **Manuel de calcul de laboratoire**, Ed. Masson & Cie, Paris, 150-2.