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METHODS OF DETERMINATION AND APPLICATION OF THE ANAEROBIC THRESHOLD FOR PERFORMANCE DIAGNOSIS

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A differentiating assessment of the performance potential under laboratory conditions, in terms of clinical diagnosis and performance physiology, requires an intimate knowledge of energy metabolism. In physical activities, energy from 3 sources is available to the organism for muscle contraction:

1. anaerobic non-lactic acid bound energy,
2. anaerobic lactic acid bound energy,
3. aerobic energy.

From these, the following performance-limiting parameters can be derived for assessing performance diagnosis:

1. Maximum oxygen uptake as an indicator of cardiac output and the oxygen transport capacity of blood indicates aerobic capacity.
2. Lactic acid concentration in capillary blood, which affects the acid base balance, indicates the maximum anaerobic capacity as well as the transition from aerobic to anaerobic energy sources (anaerobic threshold) and, in addition, serves as an indicator of maximum physical stress tolerance.

Of these parameters, the anaerobic threshold proved to be an essential criterion for performance diagnosis:

It offers practical information for optimizing training programs in sports disciplines requiring a high endurance potential, and it helps identify the tolerance limits, especially endurance performance, in coronary patients and patients undergoing rehabilitation.

Two methods are available for determining the anaerobic threshold:

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1. Metabolic determination

The anaerobic threshold is defined as a rise of lactic acid levels in capillary blood to 4,0 mmol/l. In correlation with ergospirometric data, particularly oxygen uptake and heart rate, as well as physical performance this establishes the parameters of the anaerobic threshold (Fig. 1).

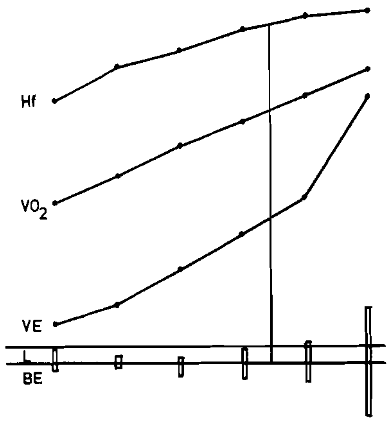

FIG. 1. - Scheme of the determination of the anaerobic threshold from a junior cyclist; lactic acid level, 4,0 mmol/l, rectangular progressive exercise procedure. Exercise intensity was increased from base line ratings by 1 W/kg every 5 minutes.

2. Ventilatory-respiratory determination

The anaerobic threshold is defined by the V_E-V_{O_2} diagram (i.e. by plotting V_{O_2} versus V_E on the coordinate system).

Ergometric plotter diagrams (Fig. 2) can equally be used for defining the anaerobic threshold. The onset of hyperventilation is marked by the intersection between the 2 straight lines of the minute ventilation volume indicating the transition from linear to nonlinear rise (see Fig. 2). This can be correlated with the oxygen uptake and the physical performance at the anaerobic threshold.

Δ_{O_2} i.e. the difference of oxygen concentration between inspired and expired air, respiratory equivalent and respiratory quotient constitute auxiliary parameters. Experience has shown that the oxygen difference slopes down, that the respiratory coefficient exceeds 0.85, while the respiratory equivalent varies from group to group, ranging from 19 to 21.

Purpose of the study

The study was designed to compare the reliance of the 2 methods under different exercise conditions.

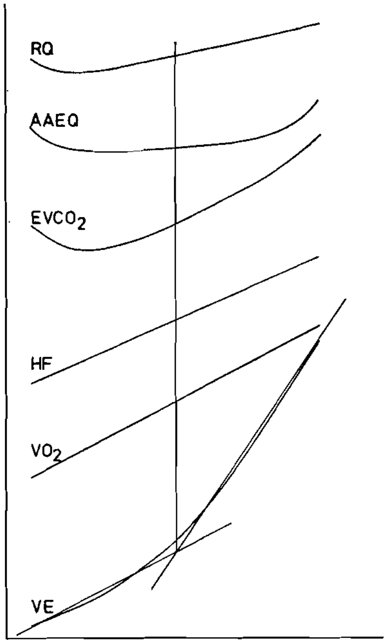

FIG. 2. - Plotter diagram; explanation, see text.

Two basic assumptions were made:

1.a. The anaerobic threshold identified by metabolic determination is used as reference, as it can be expressed in terms of a measurable metabolic quantity. This implies, however, that the exercise period must not be less than 4 minutes per work load, since it takes about 120 seconds for the potential of the cardio-circulatory system to be fully utilized and thus for aerobic energy balance to be obtained. The accuracy of determining endurance levels can be increased, if the exercise periods for each exercise intensity are a multiple of the oxygen uptake rise time, because this reduces the shares of creatinine phosphate and initial lactic acid in energy production and, proportionately to the duration of exercise periods, increases the chances of recognizing even minor anaerobic components involved in the energy balance.

b. If exercise periods are short, the blood lactic acid levels measured in a given period will reflect the concentrations corresponding to the previous period, as it takes about 120 seconds (depending on the exercise intensity) for lactic acid to be released into the blood stream.

2. When using ventilatory-respiratory determinations, the anaerobic threshold can only be assessed under triangular exercise procedure (1 minute increment test) with the rise of oxygen uptake per intensity level not exceeding 3 ml/kp/min. On account of the slow hemodynamic responses and the energy balance then imposed by anaerobic metabolism, intensity increments in excess of this value tend to produce abrupt parameter variations and thus make an accurate determination of the anaerobic threshold on the basis of V_E/V_{O_2} diagram more difficult.

Methods

The following exercise procedures were used (Fig. 3).

1. In triangular bicycle ergometry, the intensity is increased by 20 Watt/1 min.
2. In rectangular-triangular bicycle ergometry, the intensity is increased by 50 Watt/2 min.
3. In rectangular-progressive bicycle ergometry, the exercise intensity is increased by 50 Watt/5 min.

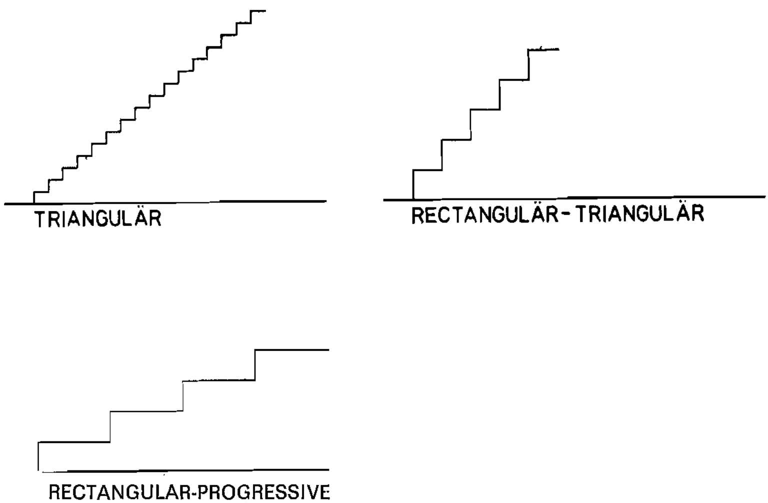

FIG. 3. - Exercise procedures; explanation, see text.

Sixteen sports students volunteered as test subjects.

Ergospirometric tests were done on an Ergo-Pneumotestsystem by E. Jaeger Company, Würzburg, Germany; test conditions were in keeping with the conditions proposed by the ICSPE committee on the standardization of ergometry. Blood samples for lactic acid determinations were obtained from hyperemic ear lobes; samples were analyzed with the Biochemical Test Combination (Boehringer Mannheim) using the method reported by Hohorst H. J.

Results

1. On rectangular-progressive exercise tests, the following values were obtained at the anaerobic threshold with metabolic determinations: 146 W, oxygen uptake 2.20 l, i.e. 31.88 ml/kp/min at a heart rate of 133. Ventilatory-respiratory determination is unproductive under these exercise conditions, because it tends to give false low values.

Table 1.

ANAEROBIC THRESHOLD	T		RT		R	
	RV	M	RV	M	RV	M
VO_2 ml/kp/min	3o.67	35.38	3o.53	34.95	25.68	31.38
VO_2 l/min	2.15	2.48	2.14	2.45	1.8	2.2o
Hf 1/min	126	136	131	139	121	133
Watt	154	18o	142	17o	12o	146
Lactat mmol/l	3.2	4.o	3.o	4.o	2.9	4.o
n = 16; age = 21.8 years; weight = 7o.1 kp; height = 197.4 cm						

2. On triangular exercise tests, ventilatory-respiratory determinations produce about identical values for oxygen uptake at the anaerobic threshold: physical performance was somewhat higher, while heart rate were lower (gradual intensity increment). Metabolic determinations, as was to be expected, produced excessively high values, the elevation corresponds to a 90 second delay of lactic acid release into the blood stream.

3. On rectangular-triangular exercise tests, metabolic determinations were found to produce excessively high, false values for the anaerobic threshold, as was to be expected. The delay due to lactic acid release was 80 seconds.

By contrast, ventilatory-respiratory determinations proved to be an accurate determination of the parameters of the anaerobic threshold.

Conclusion

1. The anaerobic threshold can be determined by two basically equivalent methods, i.e. ventilatory-respiratory and metabolic determinations.
2. In sports specific tests to identify the endurance limits of top performance athletes, preference should be given to metabolic determinations, since lactic acid determination is at any rate required for the maximum lactic acid level as a further performance-limiting factor.
3. For diagnostic ergometry in patients, normal subjects and athletes, ventilatory-respiratory determinations offer accurate values for the anaerobic threshold without lactic acid determinations, which need time and additional staff. On account of the reliability of ventilatory-respiratory determinations of the anaerobic threshold under rectangular-triangular exercise conditions and for other well-known reasons (1. the test is of short duration: 8-14 min, 2. the subjects recover rapidly, even from an exhausting test, 3. the determination of maximal V_{O_2} is probably, because it is possible to observe plateauing of V_{O_2}, 4. adaptation to increasing work rates and maximal work capacity is assessable, 5. measurements proved to be highly reproducible), this exercise pattern should be given preference.

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