RELATION BETWEEN MAXIMUM OXYGEN UPTAKE AND ANAEROBIC THRESHOLD, AND THE ROWING ERGOMETER RESULTS IN SENIOR ROWERS

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Abstract
In accordance with the worldwide achievements in the area of sports physiology, Croatian rowing has established its own protocol for controlling the competing form of rowers. The developed progressive discontinuing workload test was carried out on a rowing ergometer, and it was developed for the purpose of determining the maximum oxygen uptake and lactate anaerobic threshold, i.e. the "lactate curve". It is the finest and the most precise laboratory test in use. It is used to control the training process with the purpose of programming, i.e. reprogramming the rowers' training. The experimental section of the paper describes a test carried out on a sample of 30 rowers of the national and international calibre which demonstrated a statisticaly significant correlation between the rowing velocity at anaerobic threshold with maximum oxygen uptake (r = -0,6139). A significant individual impact of maximum oxygen uptake and rowing velocity at anaerobic threshold on the rowing simulator result at 2000m was also identified. There is a stronger correlation between the rowing velocity at anaerobic threshold and the rowing simulator result at 2000m (r = 0,72) than between the VO2max and the rowing simulator result at 2000m (r = -0,55). Taking the production of lactic acid as an indicator of the rower's competing form, it was expected, from the statistical point of wives, that it will be a highly significant predictor of the maximal test result. A strong and statistically significant co-reactive correlation between maximum oxygen uptake and lactate anaerobic threshold, as well as their strong correlation with the rowing simulator test result at 2000m, confirms the assumption that the aerobic metabolism predominantly determins the success in a 2000m rowing race (on a simulator).

Key words*: rowing, lactates, anaerobic threshold, maximum oxygen uptake*

Introduction

Testing the energetic capacities in rowers

Rowing is a type of water sport where boats are moved by the force of the rower and the oar. As an activity it belongs to the group of monostructural cyclic movements. The work of the locomotor apparatus is dominated by long-term, workload-type repetitive force, and the cardiovascular system is submitted to the endurance-type of activity of submaximum intensity over a longer period of time. Diagnostics in rowing refers to compiling relevant information about the initial, transitive and final state of athletes in terms of capacities and characteristics which are essential for success in competitive rowing. If supreme results want to be achieved, it is necessary to provide a scientific explanation for every phenomenon related to rowers' sports activities, by predicting its course and outcome, defining procedures and manners for implementing the changes, and by valorizing them as changes which occured under the influence of programmed training. In rower fitness diagnostics, a special attention is paid to the functional diagnostics. The anaerobic threshold and the maximum oxygen uptake are the most frequent parametres used in diagnostics, programming and control of the training process in rowing. The aerobic metabolism covers 75–80% of energetic demands in a rowing race. The first parameter for an assessment of aerobic metabolism is the maximum oxygen uptake or VO_2max, which refers to the level of oxygen uptake in one minute whereby a further increase of workload would no longer result in an increase in oxygen uptake (Medved, 1987). In top-class athletes who practice aerobic sports, the VO_2max values range from about 4,5 l/min up to 6 and more l/min. Top-class rowers are reported to achieve the highest VO_2max values ever measured. Those values regularly exceed 5 l/min, rather often they exceed 6 l/min, while values above 7 litres per minute have also been encountered in the professional literature. A value as high as 7,12 litres per minute has been reported (71.2 ml/kg min) in one member of the German Olympic eight from 1968 (Cunningham, 1975). The second parameter used for assessing the fitness level of rowers is the lactate anaerobic threshold, i.e. the velocity measured at the threshold. The anaerobic threshold is a metabolic response to increased exertion, i.e. the point after which energy requirements of the active musculature exceed the capacities of the aerobic metabolism, and anaerobic processes are largely activated to supply enough energy. The anaerobic lactate threshold is usually defined by means of the concentration of lactic acid in the blood in the amount of 4 mmol/l. The higher the value of workload at the anaerobic threshold, the higher the level at which the rower will be able to perform a long-term activity. The purpose of a rowing exercise is to stimulate an increased oxygen uptake, as well as to allow the rower to achieve as high a percentage of oxygen uptake as possible before the concentration of lactic acid in the blood increases significantly. Rowing contests are held in accordance with the FISA Rule Book, on a 2000 metres long course, in eight rowing disciplines for men and six rowing disciplines for women. It takes 5.5 – 8 minutes to cross the race course, which makes rowing one of the endurance-type sports. Mader, 1977 (according to Marinović, 1991) indicated that in a rowing race, 82.1% of the rower's energy derives from purely aerobic sources, while 17.9% is derived from anaerobic sources, 5.9% of which is spent on the breakdown of energy-rich phosphates, and 12% on glycolysis. During the first 10-15 seconds, which corresponds to the time in which starting strokes are performed, the maximal organism exertion occurs with the tendency to propel the boat as soon as possible from standing still to the optimum moving speed. Such extremely high workloads – 90 kCal/min, i.e. 1350 Watts; (Dorchner, 1979; according to Marinović, 1991) are performed by means of the energy obtained through the breakdown of creatine phosphate and adenosine phosphate in anaerobic conditions. The starting strokes are also characterized by a very high frequency (44-48 strokes/min) and high velocity, as well as by an extreme force in hydrodynamic drag. After the starting strokes, the optimal stroke length is achieved (as opposed to the starting strokes which are shorter) and the pace becomes slower, which results in a reduced intensity of labor. In the course of the following 2-3 minutes, the glycolytic stage of labor occurs, which is characterized by the production of a high level of lactate in the muscles. During this period, the intensity of labor can amount to 750 W. Over the course of time the consumption of oxygen gradually increases, and the eneregy is largely compensated by means of aerobic processes. After three minutes, energy is compensated by means of oxidative processes. The maximum energy turnover reaches the level of 30 kCal/min, i.e. 450 W (Dorschner, 1979; according to Marinović, 1991), which can be maintained over a longer period of time. In top-class rowers, oxygen consumption in the amount of 6000 ml/min was measured, which corresponds to about 480 Watts. Labor under relatively constant workload is maintained until the finish zone (150-300 m). In the course of those final metres workload increases again, which is basically expressed through increased investment of energy in hydrodynamic drag, as well as through an increased frequency of strokes. At the same time, apart from maximally activated oxygen consumption, the glycolitic source of energy is activated again, and such a high level of organic demands also requires a high degree of the rower's will. Important characteristics which affect the rower's specific performance can, according to Körner and Schwanitz (1985), be summarized in the following way: * VO_2max > 6.0 l/min; * Relative VO_2 > 70 ml/min; * high ergometric performance values in the transition aerobic/anaerobic area (performance at anaerobic threshold, i.e. at lactate limit values in the amount of 4 mmol/l) amounting to about 350-400 Watts; * a high proportion of VO_2max at 4 mmol/l of lactate, amounting to about 80-90%; * in the classification of muscle fibers, the 70% proportion of STF (slow-twich fibers which are aerobic in terms of metabolic processes), the increased cross section of STF and FTF (fast-twich fibers, in which metabolic processes are aerobic, with regard to the training stimulus – oxidative or anaerobic – glycolytic) in a 1:3 ratio; a high degree of capillarization proportional to the increase in the cross section of ST fibers; * a high oxidative proportion of all fibers (70-80%); * a complete metabolic differentiation of the proportion of FT fibers towards glycolitic construction; * high enzyme activities in oxidation of fats and carbohydrates, and anaerobic carbohydrate breakdown; * 80% to 20% ratio between the aerobic and anaerobic metabolism (in rowers); * a high concentration of glycogen and neutral fats in the muscle cells; * >8% proportion of the mitochondria in the cell volume; * subsarcolemmal deposition in the mitochondria; * increased level of myoglobine; * optimum rowing technique (small energy consumption for the movement structure). Based on what was previously said, it is possible to make the following general conclusion: at the beginning of a rowing race the boat is gaining speed, and the force invested by rowers ranges between 1000 and 1500 N. During the race, the speed is maintained at a lower level by means of force not greater than 500-700 N. Trained rowers are adapted to this type of exertion by means of a considerable muscle mass and high metabolic capacities. Two basic energetic mechanisms provide energy for muscle work: - Aerobic, which provides the neccessary energy by means of oxidation processes (which occur with the presence of oxygen); and - Anaerobic, where the energy is derived by means of nonoxidative processes (which occur without the presence of oxygen). In the case of anaerobic labor, there are two ways to obtain energy: anaerobic provision of energy for muscle contraction without the production of lactic acid, where energy is derived from adenosine triphosphate (ATP) and creatine phosphate (CP). This type of energy production is also called non-lactate of phosphagen. Anaerobic provision of energy for muscle contraction with the production of lactic acid, whereby energy is obtained by means of the anaerobic glycolysis process, and is also called lactate or glycolytic. The proportion and the ratio between the energy provision processes directly depends on the intensity and duration of the workload. In order to be able to perform a physical activity, it is necessary to ensure a balance between the production and consumption of energy in the musculature which is acutely active while performing the activity. How an individual will accomplish this depends on the capacity of his or her cardiorespiratory system. There is the so-called "critical intensity" of organism effort, which is the greatest intensity of exercise that an individual can carry out for an unlimited period of time without a decrease in intensity, and after which the relevant systems can no longer provide the energy for further work by means of the aerobic metabolism. Therefore, there is a turning point or a transition from mostly aerobic to anaerobic metabolism. This transition point is commonly known as the anaerobic threshold. Characteristic for the activity which is performed below the said critical point (threshold) is the possibility of a relatively infinite duration of activity, if the aspects of possible limitations due to an inhibitory effects of metabolic waste products, in particular of hydrogen ions, are the only ones taken into consideration. Above the critical level of intensity of an activity, in predominantly anaerobic conditions, the limited energy depots are spent relatively quickly and accumulation of metabolites occurs, which prevent a continuation of activities with the same intensity. Groundbreaking scientific papers by Hollmann (1959, according to Hollmann, 2001), and Wassermann and McIlroy (1964) in particular, sparked numerous research activities as well as controversy related to what is commonly known as the anaerobic threshold. The authors proposed a conceptual definition according to which the anaerobic threshold is „the intensity of exercise which involves a large quantitiy of muscle mass, above which the measured oxygen uptake cannot meet the total energy requirements". What Svedahl and MacIntosh (2003) additionally highlight when clarifying their definition of the anaerobic threshold, and what other authors fail to observe, is the necessity to apply the concept of anaerobic threshold only to those activities which involve the entire body, or at least a considerable part of the muscle mass, because in case of a local activity of one muscle or one group of muscles accumulation of lactates can occur, in which case the oxygen uptake will not correspond to the level of energy consumption. A fixed lactate model was proposed by Kindermann (1979), and it was further elaborated by Sjodin and Jacobs (1981) who introduced the term *OBLA*.

According to the original model, the anaerobic threshold was fixed at 4 mmol/l, and was preceded by the aerobic threshold at 2 mmol/l. On the basis of such a model, Skinner and McLellan (1980) proposed a possible description of the organism's energetic systems by means of two critical transition points and three stages or zones of energy provision. The intensity zone below the aerobic threshold (at about 2 mmol/l and with non-proportional increase in the V_E/VO_2 ratio) is a purely aerobic zone in which the necessary energy can be provided almost exclusively by means of the aerobic metabolism; the zone between the aerobic and anaerobic threshold, or aerobic-anaerobic transition point, corresponds to those intensities where there is a mixture of aerobic and anaerobic metabolism which provides the energy for muscle activity; while the zone above the anaerobic threshold (at about 4 mmol/l and followed by a non-proportional increase in the V_E/VO_2 ratio) is dominated by anaerobic metabolism (Bodner and Rhodes 2000).

Although objective and suitable for the purpose of an easier understanding of thresholds, this model has suffered criticism and undergone changes. It was quickly established that it is not possible to fixate the threshold at 4 mmol/l for every individual, but rather that it is necessary to identify the so-called IAT – individual anaerobic threshold. Figure 1 shows a didactically appropriate example of a curvilinear increase in lactate during a progressive running test on a treadmill. Curvilinear increase in lactate during a rowing test on a rowing simulator can be interpreted in the same way (the X-axis shows the velocity of rowing – t/500m, while the Y-axis shows lactate values – in mmol/l; it is also possible to add heart rate – HR/min). It is possible to notice an exponential growth with two turning points on the curve (aerobic and anaerobic lactate thresholds) and their projection onto the axis which shows lactate values.

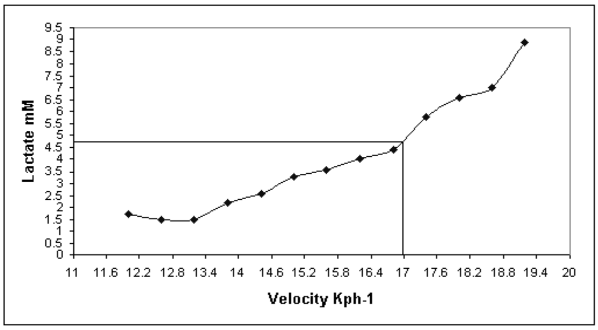

Figure 1. Curvilinear increase in lactate and turning points of the lactate anaerobic threshold

Numerous research results confirm that the anaerobic threshold is a better indicator of the aerobic endurance of athletes than the maximum oxygen uptake (Anderson and Rhodes, 1989). VO_2max has a very poor predictive power in terms of competition results. There is a rather weak correlation between the success in a race and VO_2max in athletes who have similar, i.e. high levels of VO_2max (Costil et al, 1973; and Hageberg and Coyle, 1983). Seen that the AT is a better tool for distinguishing top-class athletes in endurance sports, it is very broadly used for functional diagnostics of the athletes' fitness and for programming the training. After having reached a limit in the improvement of his or her VO_2max, an athlete can continue to improve it by means of other parametres, including the improvement of the anaerobic threshold (Weineck, 2000; Hollmann and Hettinger, 2000). By defining the anaerobic threshold, zones of the training workload intensity can also be defined for an individual athlete. The workload below or around the threshold level can be defined as moderate, the workload significantly below the threshold level can be defined as mild, while the workload above the threshold level can be defined as intensive. The methods used to assess the aerobic endurance can be direct or indirect. Direct methods directly define the intensity which can be maintained for as long as possible, and consequently the highest relative intensity for a given duration or distance.

Indirect methods, which also include the method for defining the anaerobic threshold, do not require a maximum duration of measurement, i.e. a concrete demonstration of what the anaerobic threshold measures by definition, but they take into account several workloads during a defined period of time which are assumed to reflect the level of aerobic endurance. The Maximum Lactate Steady State (MLSS): the MLSS represents the highest intensity of exercise whereby the concentration of lactate in blood does not increase during a continuous exercise under a defined workload (Tegtbur et al 1993). In other words, according to Heck et al (1985), the workload in MLSS represents the intensity of exercise at which there is a balance between the production of lactate and its elimination from the blood.

When measuring the MLSS, it is necessary to carry out multiple workload tests, each under a constant workload, so that a certain range of intensity is covered in which the steady state is expected to occur. Individual constant workloads last no less than 20 minutes, and usually 30 or more minutes. In the initial stage of each level of workload there is a curvilinear increase in lactate in blood, and depending on whether the given workload is below, on, or above the steady state level, the curve continues to either drop, or maintain the reached trend, or constantly increase (See Figure 2). The criterion which defines the level at which, under a given intensity of constant workload in the last 20 minutes of the test, a change can occur in the lactate concentration varies among different authors, ranging from 1 mmol (Heck et al, 1985; Swensen et al, 1999), to the more strict criteria of 0,5 to 0,2 mmol (Haverty et al, 1988; Aunola and Rusko, 1992). The problem with direct measurement of MLSS is how to define a reasonable range within which steady state occurs in athletes. Usually, preliminary tests are used which define the level of increase in intensity, whereby the increase of 4-5% is usually applied (Svedahl and MacIntosh, 2003; Stegman and Kindermann, 1982). A disadvantage with the direct MLSS measurement is that it requires a lot of time and several visits to the laboratory.

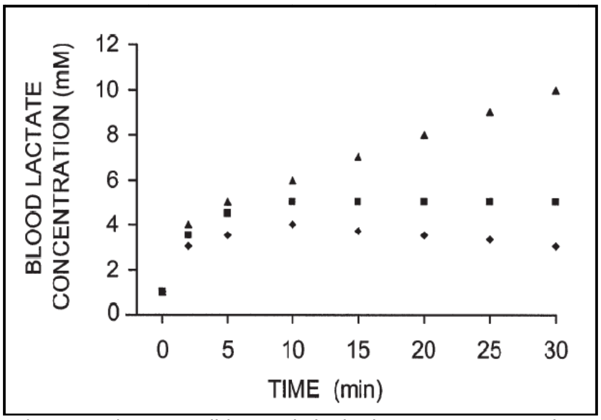

Figure 2. Three possible trends in the lactate curve over time under constant and various levels of workload, depending on whether the workload intensity is below (diamonds), on (squares), or above (triangles) the steady state (model according to Svedahl and MacIntosh, 2003).

By definition, the lactate threshold is defined at the intensity of exercise which is associated with a significant increase in blood lactate concentration above the standing-still level, during a progressive workload test (Svedahl and MacIntosh, 2003). There are different criteria for identifying such an increase. Considering the criteria for determining a considerable lactate increase, we distinguish between two ways of defining the lactate threshold: the OBLA, and the individual anaerobic threshold (IAT). The OBLA (Onset of Blood Lactate Accumulation): in the course of the test, the intensity of exercise is identified under which lactate concentration reaches 4 mmol/l during a progressive workload test (Sjodin et al, 1981). This method uses the 4 mmol/l value as the reference point, which has its advantages in terms of objectivity, but it also has disadvantages as it neglects individual differences. Namely, not all participants in a test will demonstrate a significant lactate increase at 4 mmol/l; rather, the range is rather broad, ranging from 3 to 6 mmol/l, and according to some authors it can reach as much as 9 mmol/l (MacIntosh et al, 2002; Billat et al, 2003). The Individual Anaerobic Threshold (IAT): represents the interpretation of the lactate threshold which occured after the existence of interindividual differences in lactate concentration at the lactate anaerobic threshold has been confirmed.

There are different methods for defining the IAT, but one of the most familiar and probably the most commonly used ones is the one which defines the IAT as the intensity of exercise identified by means of a tangent line drawn from the lactate recovery concentration (which corresponds to the concentration at the final workload level) onto the curve of lactate concentration measured during a progressive workload test (See Figure 3).

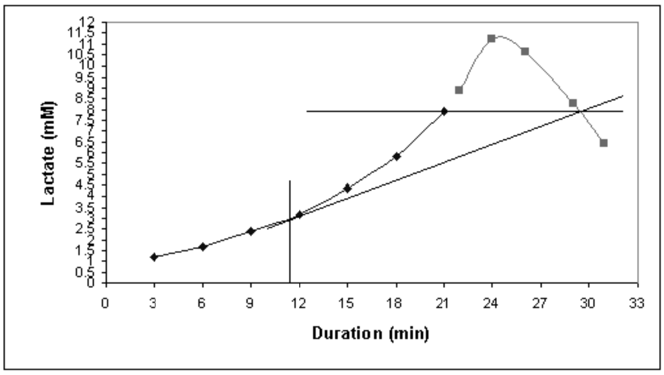

Figure 3: The usual lactate curve which shows an exponential increase in lactate due to an increase in workload intensity. The solid line represents the tangent which identifies the IAT.

This method for identifying the individual lactate threshold does not require expensive equipment, nor special training or maximal exhaustion of the participants in the test, which is why it is very practical and often used in the sports practice. Its disadvantages are that it is very sensitive to the applied workload protocol in terms of the type of activities (rowing ergometer, bicycle ergometer or treadmill), the initial workload, the amount of workload increase, the duration of each individual workload level, the duration of the break, the treadmill tilt angle, the application of continuing or discontinuing protocol, and the state of the intramuscular glycogenic depot. Ventilation threshold: It represents the intensity of exercise under which there is an increase in all ventilation parametres which become disproportionate with the increase in intensity during a progressive workload test (Svedahl and MacIntosh, 2003).

Methods

The *goal* of this scientific paper was to establish a correlation between lactate anaerobic threshold (4 mmol/l) and maximum oxygen uptake in rowers of the national and international calibre while using the "Concept II" rowing ergometer. The *sample* consisted of 30 rowers of national and international calibre whose age, height and weight are shown in the Table 1.

Table 1. Anthropometric characteristics of participants in the test

	Rowers (n = 30)
AGE (years)	23,01 ± 3,40
HEIGHT (cm)	190,92 ± 4,28
BODY MASS (kg)	89,34 ± 5,34

Sample of physiologically functional variables: 1) *LA4INT* – rowing velocity at the anaerobic threshold (sec/500m), 2) *LA4VOA* – absolute oxygen uptake at the anaerobic threshold (l O_2/min), 3) *LA4VO%* – percentage of VO_2 at the VO_2max threshold (%), 4) *LA4HR* – heart rate at the lactate anaerobic threshold (heart beat/min), 5) *LAMAX* – lactate level after the final maximal stage (mmol/l), 6) *VO2MAX* – absolute maximum oxygen uptake (l O_2/min), 7) *VO2REL* – relative maximum oxygen uptake (ml O_2/min/kg), 8) *HRMAX* – maximum heart rate (heart beat/min), 9) *E2000* – time result on a rowing ergometer at 2000m (sec).

The testing was carried out on the "Concept II" rowing ergometer which offers a very faithful simulation of workload in the boat, with a continuous monitoring of workload data (expressed in Watts, m/s, or Kal/h), stroke frequency and invested labor (expressed in metres and joules) for each individual stroke, as well as for the total duration of the activity. A discontinuing progressive test on the "Concept II" rowing ergometer was used, with four-minute workload stages. The initial workload was set according to the individual capacities and level of fitness. During two-minute breaks, blood was taken from the athletes' earlaps one minute into the break, in order to determine the lactate curve and the lactate anaerobic threshold. The workload was increased linearly by 3 seconds from one level to the next having passed 500m, while the rower / participant in the test did not reach the level of 4 mmol/l of lactic acid in blood.

After detecting the lactate values which exceeded 4mmol/l, the final workload level took place, lasting 3 minutes; however, during the last 90 seconds the athletes rowed with maximum possible intensity in order to reach maximal values of aerobic capacity. The lactic acid concentration in blood was determined by means of the "Lactate analyser YSI MODEL 23L" device developed by Yellow Springs Instr. Co., while spirometric values were recorded by means of the „MasterLab" device developed by Jeager company. Heart rate was measured constantly by means of the Polar pulsometer. The recorded dat was processed by means of a standard computer programme for the analysis of metric properties within the internal consistency model of the Statistica for Windows statistical software.

Results

Table 2. Descriptive parametres of the aerobic capacity values and the lactate anaerobic threshold

	N	AM	MIN	MAX	SD
AGE	30	23,01	16,29	30,83	±
HEIGHT	30	190,92	182	200	±
MASS	30	89,34	75,5	98	±
LA4INT	30	102,28	98	107,5	±
LA4VOA	30	5,06	4,32	6,16	±
LA4VO%	30	88,09	76,81	94,24	±
LA4HR	29	177,52	164	193	±
LAMAX	29	9,91	7,4	12,1	±
VO_2MAX	30	5,69	4,65	6,9	±
VO_2REL	30	64,14	57,33	72,7	±
HRMAX	30	193,07	175	207	±
E2000	30	372,2	357	392	±

(N – Number of participants in the test, AM – arithmetic mean, MIN – minimum, MAX – maximum, SD – standard deviation)

Table 3. Results of the regression analysis of the impact of predictors (maximum oxygen uptake and lactate anaerobic threshold) on the criterion variable (ergometer result at 2000m)

	r	Beta	B	t(27)	st
LA4INT	0,70	0,58	2,31	3,40	0,002
VO_2MAX	-0,55	-0,20	-4,22	-1,17	0,253

R = multiple correlation, Rd^2 = coefficient of determination, F = F-test value, st = significance threshold, r = correlation coefficient, Beta = standardized regression coefficient, B = regression coefficient, t = t-test value, st = ignificance threshold, df = degrees of freedom (n-1)

Table 3 shows the influence of the predictor variables (VO_2max and anaerobic threshold velocity) with the criterion variable (test result at 2000 m on a rowing simulator). By means of a statistical analysis we have determined that a group of predictor variables VO_2max and LA4INT have a statistically significant impact ($p<0,00004$) on the criterion variable result, i.e. on the 2000m result on a rowing simulator. Two predictor variables explain 51,4% ($RD^2 = 0,514$) of the criteria, i.e. ergometer results at 2000m. Seen that the multiple correlation coefficient is statistically significant, it can be said that, as expected, the predictor variable of the rowing velocity at the anaerobic threshold has a significant impact on the criterion variable – the 2000m result on the ergometer. The regression coefficient (B = 2,31) demonstrates a positive dependence of results, i.e. a "better score" by 1 second at 500m at the anaerobic threshold (4mmol/l), which will on average reduce the ergometer result to 2000m in 2,31 seconds.

Table 4. Correlation matrix

	LA4INT	LA4VOA	LA4VO%	LA4HR	LAMAX	VO_2MAX	VO_2REL	E2000
LA4INT	1.00							
LA4VOA	-0,79	1.00						
LA4VO%	-0,30	0,40	1.00					
LA4HR	-0,08	0,02	0,2	1.00				
LAMAX	0,15	0,01	-0,31	-0,11	1.00			
VO_2MAX	-0,61	0,72	-0,19	-0,08	0,14	1.00		
VO_2REL	-0,33	0,48	-0,28	-0,19	0,21	0,60	1.00	
E2000	0,72	-0,73	-0,26	0,19	0,05	-0,55	-0,30	1.00

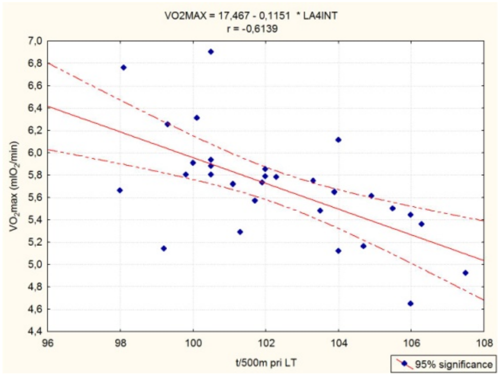

Figure 5. Relationship between VO_2max and 500m score at the lactate anaerobic threshold (4 mmol)

Conclusion

In accordance with the worldwide achievements in the area of sports physiology, Croatian rowing has established its own protocol for controlling the competing form of rowers. A progressive discontinuing workload test on a rowing ergometer for the purpose of determining the maximum oxygen uptake and lactate anaerobic threshold, i.e. the "lactate curve", is the most common, the finest and the most precise laboratory test which is used for programming and control of the training process in rowing, while on the other hand, maximum oxygen uptake and lactate anaerobic threshold are the most common parametres used in diagnostics, programming and control of the training process in rowing. This paper establishes a statistically significant correlation between the velocity of rowing at anaerobic threshold and maximum oxygen uptake (r = -0,6139), which is shown graphically in Figure 5. The correlation is a negative one, as the velocity of rowing is expressed by means of the score at 500 meters (sec/500m), a unit which is

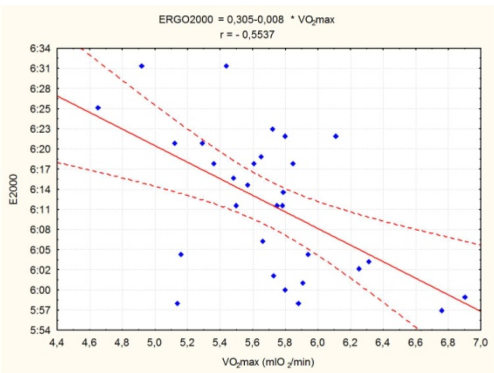

Figure 6. Correlation between the E2000 and VO_2max test results

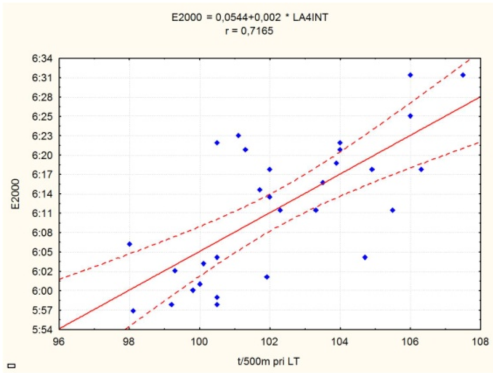

Figure 7. Correlation between the E2000 test results and velocity at threshold

most frequently used in practice and which is inversely proportional to velocity. Also, a significant individual impact of maximum oxygen uptake and rowing velocity at anaerobic threshold on the rowing simulator result at 2000m was identified. There is a more significant correlation between rowing velocity at anaerobic threshold and the rowing simulator result at 2000m (r = 0,72) than between VO2max and the rowing simulator result at 2000m (r = -0,55). Taking the production of lactic acid as an indicator of competing form of rowers, it was expected that from the statistical point of view it will be a highly significant predictor of the maximal test result. A strong correlation between the maximum oxygen uptake and lactate anaerobic threshold, as well as their strong correlation with a succesfull rowing simulator test result at 2000m confirms the assumption that the aerobic metabolism is dominant, and that it dominantly determins the success in a 2000m long rowing race (on a simulator).

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ODNOS MAKSIMALNOG PRIMITKA KISIKA I ANAEROBNOG PRAGA, I REZULTATI VESLAČKOG ERGOMETRA KOD STARIJIH VESLAČA

Sažetak

U skladu sa svjetskim dostignućima na području sportske fiziologije, hrvatsko veslanje je uspostavilo vlastiti protokol za kontrolu natjecanja veslača. Razvijen je progresivni test radnog opterećenja obavljen na veslačkom ergometru, a bio je razvijen u svrhu utvrđivanja maksimalnog primitka kisika i laktata anaerobnog praga, odnosno "laktatne krivulje". To je najbolji i najprecizniji laboratorijski test u uporabi. Koristi se za kontrolu trenažnog procesa s ciljem programiranja, odnosno reprogramiranja treninga veslača. Eksperimentalni dio ovog rada opisuje ispitivanje provedeno na uzorku od 30 veslača na nacionalnoj i međunarodnoj razini gdje je dobivnea statistički značajna korelacija između brzine veslanja na anaerobnom pragu s maksimalnim primitkom kisika (r = -0,6139). Značajan pojedinačni utjecaj maksimalnog primitka kisika i brzina veslanje na anaerobni prag na rezultat u veslanju simulatora na 2000m također je identificiran. Tu je jača korelacija između brzine veslanje na anaerobnom pragu i rezultatu veslanja simulatora na 2000m (r = 0,72), nego između VO2max i rezultata veslanja simulatora na 2000m (r = -0,55). Uzimajući proizvodnju mliječne kiseline kao pokazatelj natjecateljskog oblika veslanja, što se i očekivalo, iz statističke točke žene, da će to biti vrlo značajan prediktor maksimalnog testa. Jaka i statistički značajna korektivna korelacija između maksimalnog primitka kisika i laktata anaerobnog praga, kao i njihove jaka povezanost s veslačkim simulatorom rezultata testa na 2000m, potvrđuje pretpostavku da aerobni metabolizam pretežno utvrđuje uspjeh u veslanju 2000m utrke (na simulatoru).

***Ključne riječi**: veslanje, laktati, anaerobni prag, maksimalni primitak kisika*

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