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CHANGES IN PHYSICAL PERFORMANCE OF AMATEUR MOUNTAIN BIKERS IN THE PREPARATORY PERIOD

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Abstract

Introduction. The aim of the research was to assess the changes in the main physical performance indicators, i.e. maximum oxygen uptake (VO_{2max}), the threshold of anaerobic changes (AT) and "exercise efficiency" (oxygen consumption/power; VO_2/WR) in amateur mountain bikers in the preparatory period. In addition, diagnostic usefulness was made of selected respiratory, circulatory and metabolic parameters to assess the training progress in cycling. ***Materials and methods.*** Thirty-six men training in amateur mountain biking took part in the research. Each of them underwent three ergospirometry tests at the beginning, in the middle (after 7 weeks) and at the end of the preparatory period (after 14 weeks). The results obtained at the AT threshold and at maximum effort were analysed to check how physical training in the preparatory period affected selected exercise parameters. ***Results.*** No significant changes in the VO_{2max} value were observed during the preparatory period, but a significant increase in this indicator (in absolute terms and in terms of body weight) was found at the AT level. An increase was noted in power as well as in measured metabolic, ventilation and circulatory parameters with the exception of heart rate and ventilation equivalent oxygen. VO_2/WR decreased, which indicates an improvement in the effectiveness of the effort. ***Conclusions.*** For Polish amateur cyclists with extensive training experience, the most diagnostic indicators in the preparatory period include improving the AT threshold (shift towards higher % VO_{2max} and higher generated power) and increasing exercise efficiency.

Key words: amateur mountain bikers, ergospirometry test, training cycle

Introduction

Physical performance test on cyclists

At the stage of preparation for the competition, the ergospirometry test (CPET) is a professional training and diagnostic tool. It consists in registering the value of respiratory parameters – minute ventilation of the lungs and changes in the composition of the respiratory air caused by the gradually increasing load on the cycloergometer. The test ends when the participant reaches their maximum abilities and cannot continue their effort [1]. Based on the results obtained, the training recommendations and plans are optimised and, at the end of the training period, another test verifies the effectiveness of the implemented training programme. The improvement in exercise capacity in cyclists with several years of training experience is expected after the preparatory period. It aims to increase the athlete's effort capabilities so that their disposition is high for racing during the competition period. This is the time in which, through training with an intensity below the AT threshold, long-term riding abilities which do not cause an increase in blood lactate concentration are mainly shaped [2]. If you want to assess the change in the athlete's physical performance parameters during the preparatory period, you should check their initial disposition after the training period – usually at the end of December. Then, the cyclist returns to regular cycling training to prepare them for competition. The first competitions usually take place at the end of April.

The main indicators of physical performance measured in cyclists

Exercise physiologists and coaches operate with many exercise parameters. It is believed that, in endurance sports, three indicators play the largest role: maximum oxygen uptake (VO_{2max}), anaerobic transformation threshold (AT) and exercise efficiency which is understood as the ratio between oxygen uptake and effort power (VO_2/WR) [3]. The load corresponding to AT and VO_{2max} determine the effort that can be made for a certain time. If the effort is below AT, it can last for several hours. However, after exceeding this intensity of exercise, the increased muscle energy demand can no longer be satisfied with fat oxidation and, therefore, glycogenolysis is stimulated and the glycolysis process is activated. As a result of exceeding the possibility of pyruvate oxidation in mitochondria, lactate and hydrogen ion are formed, which increases fatigue and reduces physical exertion [3, 4].

The effort at the VO_{2max} level provides information on the athlete's maximum capability of aerobic resynthesis ATP. The more oxygen the athlete has for use in muscle work, the more efficient they will be, which is why athletes in endurance sports strive to achieve high values of this indicator. However, even the best athletes are unable to maintain the intensity of the effort corresponding to VO_{2max} during several minutes of effort [3, 5].

VO_{2max} and AT reflect the amount of chemical energy released in the processes of aerobic metabolism and anaerobic glycolysis. Only a part of this energy is converted into the mechanical energy of movement related to e.g. cycling. Effective effort determines the relationship between these quantities thereby indicating how much energy which is released from metabolic changes is then spent on useful work related to overcoming cycling resistance, and how much is lost on heat energy. It has been estimated that the oxygen cost understood as the amount of oxygen needed to burn energetic substrates in order to obtain energy equal to the mechanical energy of movement for total oxygen uptake changes under the influence of training, positioning on a bicycle and other factors in the range of 20-30%. After this improvement, the athlete will be able to generate higher power with the same oxygen consumption [3, 6].

There were many works in which the authors compared performance parameters at various stages of preparation for the competition [7, 8, 9]. It would seem that the issue related to the assessment of physical performance in cyclists has been exhausted. However, these comparisons usually concerned professional athletes. This paper describes the impact of cycling training on aerobic capacity in Polish amateur cyclists. Amateur cycling has developed in recent years and, at the same time, a small number of works with the participation of Polish amateur cyclists is observed. Therefore, it is justified to pay more attention to this group and to attempt to assess the efficiency of cyclists in the training cycle.

Aim of the research

The aim of the research was to assess the changes in the main physical performance indicators (VO_{2max}, AT and VO_2/WR) in the preparatory period of amateur mountain bikers. In addition, diagnostic usefulness was made of selected respiratory, circulatory and metabolic parameters to assess training progress in mountain biking.

Materials and methods

Thirty-six amateur mountain bikers took part in the research. Selection for the examined group took place according to strictly defined criteria: training experience (over 5 years), age (in the range of 20-40 years) and a high national sports level. The sports level was assessed taking into account TOP 20 in the general classification (without age categories in amateur cycling races) and MTB marathons throughout the country (competitors participating in any races in the series: Mazovia MTB Marathon, Poland Bike, Marathons Kresowe, Milko Mazury MTB). The characteristics of the respondents are presented in table 1.

The research was conducted in the preparatory training period. Each athlete performed three ergospirometry tests: at the beginning (in January), in the middle (after 7-8 weeks – March) and at the end of the preparatory period (after 7-8 weeks – April) (Fig. 1).

The participants performed a performance test until exhaustion on a bicycle ergometer. The exercise protocol described in other studies was carried out to assess physical performance of professional cyclists [10]. The test began with a 2-minute recording of the respiratory parameters and resting heart rate. The next phase was an effort with 50W, from which the load increased in a linear way (ramp protocol) by 25W every minute. The riders maintained the cadence range of 70-90 rpm. The test was interrupted when the competitor reported the inability to continue the test or to maintain the set power. All competitors participating in the study had previous experience in this type of tests.

A portable MetaLyzer 3B-R3 ergospirometer from Cortex Biophysik GmbH and a Cyclus2 bike trainer from RBM Elektronik-Automation GmbH were used in the study. The devices were successfully calibrated in accordance with the manufacturer's instructions. The measurements of the power generated by the cyclist (WR), minute lung ventilation (VE), oxygen uptake (VO_2), oxygen equivalent (VE/VO_2), heart rate (HR), oxygen pulse (VO_2/HR) and oxygen power (VO_2/WR) were made. The value of the AT threshold was determined using the v-slope method, ventilation equivalents and partial pressures [11].

The competitors implemented the training plan according to the guidelines of their coaches. They trained with a volume of 9-17 training hours per week. In the first mesocycle (January-March), apart from cycling, the competitors ran, swam and performed gym exercises. In the second mesocycle (March-April), they mainly rode a bicycle. Most of the time (70-80%) they trained below the AT threshold.

For the statistical analysis of the collected material, mean values and standard deviations were calculated, and the analysis of variance (ANOVA) was used for repeated measurements. The measured parameters were dependent variables, and the independent controlled variable was the impact of physical training on the athlete's performance. Statistical significance was adopted at the level of $p < 0.05$. In the event of statistically significant differences in parameter values in the subsequent tests of the preparatory period, a Tukey's test was performed for post-hoc comparisons. Calculations and statistical analyses were performed using Statistica and Excel computer programmes.

Results

The results of the statistical analysis of the parameters obtained at the AT threshold are shown in Table 2, corresponding to the maximum effort shown in Table 3. In the first case, a highly significant improvement in the VO_2, VO_2/kg, WR, WR/kg, VE and % VO_{2max} threshold parameters was observed, which

Table 1. Characteristics of the examined group

Parameters	Average values ± SD
Age (years)	30.0 ± 6
Body weight (kg)	75.8 ± 10
Body height (cm)	176.0 ± 17
VO_{2max} at the beginning (ml/kg/min)	60.0 ± 6
Training experience (years)	6.5 ± 1.23

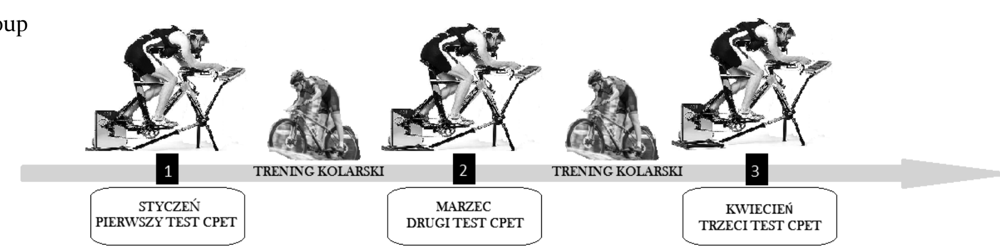

Figure 1. Graphic representation of the stages of the study. The first CPET checked competitors' performance before regular training in the preparatory period. During the next 7-8 weeks, the athletes trained based on the results and guidelines of their coach. At the beginning of March, the CPET test was repeated to check if there was a change in their physical performance. During the next 7-8 weeks, the competitors implemented the training plan, which ended with the third (last) CPET test

Table 2. The results of ANOVA of the physiological parameters obtained at the anaerobic transformation threshold (AT) during the preparatory period

Variables	Unit	SS	Df	MS	F	p-value	Test F
Body weight	kg	15.352	2	7.67593	6.70402	**0.00217**	3.12768
WR (AT)	W	14366.463	2	7183.23148	24.60628	**0.00000**	3.12768
WR/kg (AT)	W/kg	3.259	2	1.62954	31.67729	**0.00000**	3.12768
VO_2 (AT)	l/min	0.779	2	0.38971	8.75880	**0.00040**	3.12768
VO_2/kg (AT)	ml/kg/min	200.056	2	100.02778	17.33393	**0.00000**	3.12768
HR(AT)	beat/min	51.167	2	25.58333	0.64046	0.53011	3.12768
VE (AT)	l/min	997.004	2	498.50176	14.68908	**0.00000**	3.12768
VO_2/HR (AT)	ml/beat	36.796	2	18.39815	5.12680	**0.00836**	3.12768
VO_2/WR (AT)	l/min/W	5.658	2	2.82916	7.33693	**0.00128**	3.12768
VE/VO_2 (AT)	-	7.847	2	3.92327	2.70199	0.07407	3.12768
%VO_2 (AT)	%	458.302	2	229.15098	10.24511	**0.00013**	3.12768

WR – power generated, VO_2 – oxygen uptake, HR – heart rate, VE – minute lung ventilation, VO_2/HR – oxygen pulse, VO_2/WR – oxygen power, VE/VO_2 – oxygen equivalent

Table 3. The results of ANOVA of the physiological parameters obtained at the maximum values (max) during the preparatory period

Variables	Unit	SS	Df	MS	F	p-value	Test F
Body weight	kg	15.352	2	7.67593	6.70402	**0.00217**	3.12768
WR max	W	4868.130	2	2434.06481	8.25592	**0.00060**	3.12768
WR/kg max	W/kg	1.633	2	0.81667	8.47349	**0.00051**	3.12768
VO_2 max	l/min	0.017	2	0.00842	0.19342	0.82457	3.12768
VO_2/kg max	ml/kg/min	5.389	2	2.69444	0.28522	0.75272	3.12768
HR max	beat/min	56.519	2	28.25926	0.25094	0.77876	3.12768
VE max	l/min	140.167	2	70.08333	1.31812	0.27420	3.12768
VO_2/HR max	ml/beat	2.056	2	1.02778	0.58677	0.55883	3.12768
VO_2/WR max	l/min/W	4.629	2	2.31443	7.10021	**0.00156**	3.12768
VE/VO_2 max	-	11.641	2	5.82053	1.66724	0.19618	3.12768

WR – power generated, VO_2 – oxygen uptake, HR – heart rate, VE – minute lung ventilation, VO_2/HR – oxygen pulse, VO_2/WR – oxygen power, VE/VO_2 – oxygen equivalent

Table 4. Average values and standard deviations of the variables determined for anaerobic transformation threshold (AT) during the preparatory period for the tested cyclists. Statistically significant differences in parameter values between tests: A – first and second, B – second and third, C – first and third

Variables	Unit	Symbol of statistically significant differences	Ergospirometry test		
			1st	2nd	3rd
Body weight	kg	C	75.8 ± 10	75.6 ± 10	74.9 ± 10
WR (AT)	W	ABC	252 ± 35	267 ± 42	281 ± 38
WR/kg (AT)	W/kg	ABC	3.37 ± 0.46	3.6 ± 0.52	3.79 ± 0.53
VO_2 (AT)	l/min	C	3.21 ± 0.38	3.32 ± 0.49	3.42 ± 0.4
VO_2/kg (AT)	ml/kg/min	AC	42.69 ± 4.66	44.72 ± 5.21	46 ± 5.25
HR (AT)	beat/min	-	156 ± 9	158 ± 10	158 ± 13
VE (AT)	l/min	BC	80.6 ± 10.4	83.8 ± 13	88 ± 13
VO_2/HR (AT)	ml/beat	AC	20.6 ± 2.74	21.9 ± 4.3	21.8 ± 3.3
VO_2/WR (AT)	l/min/W	C	12.78 ± 0.8	12.51 ± 1.1	12.22 ± 0.7
VE/VO_2 (AT)	-	-	25 ± 2	25 ± 2	26 ± 2

WR – power generated, VO_2 – oxygen uptake, HR – heart rate, VE – minute lung ventilation, VO_2/HR – oxygen pulse, VO_2/WR – oxygen power, VE/VO_2 – oxygen equivalent

Table 5. Average values and standard deviations of the variables determined for the maximum effort (max) during the preparatory period for the tested cyclists. Statistically significant differences in parameter values between tests: A – first and second, B – second and third, C – first and third

Variables	Unit	Symbol of statistically significant differences	Ergospirometry test		
			1st	2nd	3rd
Body weight	kg	C	75.8 ± 10	75.6 ± 10	74.9 ± 10
WR max	W	AC	400 ± 49	411 ± 50	417 ± 48.6
WR/kg max	W/kg	BC	5.32 ± 0.7	5.43 ± 0.83	5.62 ± 0.72
VO_2 max	l/min	-	4.51 ± 0.45	4.52 ± 0.47	4.49 ± 0.52
VO_2/kg max	ml/kg/min	-	60 ± 6	60.6 ± 6.88	60.47 ± 7.28
HR max	beat/min	-	187 ± 7	186 ± 9	187 ± 18
V'E max	l/min	-	165.7 ± 20	166.3 ± 23	168.8 ± 24.7
VO_2/HR max	ml/beat	-	24.2 ± 2.9	24.5 ± 3.1	24.5 ± 3.3
VO_2/WR max	l/min/W	C	11.32 ± 0.8	11.05 ± 0.7	10.81 ± 0.8
VE/VO_2 max	-	-	37 ± 3.5	37 ± 4	38 ± 3.85

WR – power generated, VO_2 – oxygen uptake, HR – heart rate, VE – minute lung ventilation, VO_2/HR – oxygen pulse, VO_2/WR – oxygen power, VE/VO_2 – oxygen equivalent.

was accompanied by a significant reduction in body weight and an improvement in VO_2/HR and VO_2/WR. No changes in HR and VE/VO_2 were observed at the AT threshold. However, the results of the statistical analysis were different for these parameters measured at maximum effort. A highly significant improvement was observed only for WR and WR/kg, and a significant improvement was noted in VO_2/WR. No changes were observed for VO_2, VO_2/kg, VE, VO_2/HR, HR and VE/VO_2.

Tables 4 and 5 present average values and standard deviations of the variables determined for the anaerobic transformation threshold (AT) and maximum values (max) during the preparatory period for the tested cyclists.

Discussion

The most important achievement of the research conducted on Polish amateur cyclists was the assessment of the diagnostic value of many cardiopulmonary indicators in the training cycle. In addition, changes in exercise adaptation were characterised in athletes who underwent the 3-month training in the preparatory training period. It should be emphasised that competitors at a relatively high level took part in the study, as evidenced by their place at the forefront of national marathons.

In the first test, the average VO_{2max} value was 4.5 ± 0.5 l/min, which was 60 ± 6 ml/min/kg in terms of body weight. The results obtained are 13% higher than the values obtained for untrained individuals and comparable to the results of other amateur cyclists from Poland [9, 7]. However, the obtained VO_{2max} was 11-30% lower than that of professional cyclists [12, 13].

One of the key factors indicating an improvement in performance under the influence of training that will bring these athletes closer to achieving success in the competition will be the increase in VO_{2max}. How to explain the lack of significant changes in this parameter in the studied cyclists in the analysed preparatory period?

Swimmers and long-distance runners over 20-25 years of age reported that their ability to exercise and the value of VO_{2max} decrease with age [14]. It was shown that in top rowers, VO_{2max} increases until 23 years of age, and then increases little or does not change [15]. VO_{2max} also remains stable in professional adult cyclists [8, 16]. A possible reduction in the value of this parameter results from the generation of lower power associated with returning to training after injury or after training. In our own research, a high average age of cyclists (30 ± 6 years) and relatively long training experience (over 5 years) could have been the reason for the lack of significant changes in this indicator during the preparatory period.

Oxygen capacity under the influence of training can increase by 6-20%, with the largest changes in VO_{2max} expected for people who have a sedentary lifestyle and have started training [17]. The basis of VO_{2max} growth is the improvement in morphology and cardiovascular function resulting from training. The greatest impact is the improvement in the cardiac output caused by eccentric hypertrophy. Other changes include an increase in the diameter of important arterial vessels and an increase in capillary density, enabling greater perfusion and extraction of oxygen in skeletal muscles [6, 18]. No changes in the amount of maximum oxygen intake during the preparatory period in the tested cyclists could indicate their optimal level of training, an excessively short observation period or it could be related to their training plan.

It was noted in well-trained athletes that if the main element of training is volumetric training, and exercises with high intensity are neglected, then there is no improvement in VO_{2max} [19]. Also, if the tested athletes did not change their training method for a long time before and during the experiment, then, after the observation period began, the training carried out within a period of three months could not provide an effective stimulus for further adaptation [19].

The power registered in the maximum effort in the first period was 400 ± 49W, which corresponded to 5.3 ± 0.7W/kg. In the subsequent tests, higher power was obtained with no changes in VO_{2max}. In the second test period, the absolute power value increased by 2.5%, while in the third, by 1.5%.

In the present study, the maximum HR and VO_2/HR values did not show significant changes during the preparatory period. In other works [20], no relationship was found between the HR_{max} and training level. Oxygen heart rate is a calculated parameter, not a measured parameter, and its average value at maximum effort was 24 ml/stroke. It was confirmed that the parameters constituting the components of VO_{2max} and HR_{max} in this group of competitors are stable and do not change under the influence of training over a period of 3 months.

At the end of the training period, the body weight of the cyclists was lower than the baseline measured in January. Most physical performance assessment parameters are expressed in relative units, i.e. converted body weight. The optimal solution in sport is to strive for weight loss at the expense of body fat. If it is caused by a reduction in lean body mass or by dehydration, in both cases it may result in a decrease in strength and physical performance.

The AT threshold is another significant indicator of physical performance in endurance sports. Up to this intensity of exercise expressed in % VO_{2max}, WR or HR, you can perform prolonged effort without a sharp increase in blood lactate and the need to reduce the intensity or to stop exercising. It is believed that the AT threshold is susceptible to changes in response to prolonged training [21]. Its shift towards higher VO_2 and WR in an athlete representing an endurance sport may be an important factor that will bring them closer to achieving a better result in competition.

In healthy individuals leading a sedentary lifestyle, the % VO_{2max} measured at the AT threshold from VO_{2max} is usually 50-60%, which means that a fourfold increase in the resting value of VO_2 already causes an increase in blood lactate [22]. In professional cyclists, lactate in the blood begins to increase at a load corresponding to only 75-90% of VO_{2max}, which is about 10 times more than the resting value [3]. In the first CPET test, the cyclists set an AT threshold of 71% VO_{2max} (a tenfold increase in resting VO_2).

To meet the requirements of their sport, riders must significantly and regularly exceed the intensity of efforts typical of untrained individuals. Amateur cyclists trained 70-80% of the training time below the AT threshold. Such training mainly involves type I slow-contracting muscle fibres. Work in this area increases the number of mitochondria in working muscles, thanks to which the intensity range in which fats will be the main source of energy increases, and it is only with considerable effort that the share of carbohydrates will increase [2, 23]. Lower carbohydrate consumption results in less lactate production in exercised muscles. The effect of this training was observed in the tested cyclists in the preparatory period, which was expressed by a significant increase in threshold power.

The AT threshold at the beginning of the preparatory period corresponded to 71% VO_{2max} and after three months of training increased significantly to 76%. For competitors who have the same VO_{2max} values, a person with a higher % VO_{2max} will achieve better results. Coyle and co-authors [5] studied cyclists with similar VO_{2max}, who they divided into two groups, i.e. with a low AT threshold of 65.8% VO_{2max} and a high 81.5% VO_{2max}. Everyone made an effort on 88% VO_{2max}. Cyclists with low AT percentages, respectively, were able to maintain this effort for 29 mins, and lactate levels increased to 14.7 mmol/l, while riders with high percentages continued to exercise for 61 mins, and lactate levels increased to 7.4 mmol/l. These data confirmed the fact that a high % VO_{2max} is important in sports where you need to keep your effort for a long time to increase your exercise time and delay fatigue caused by an increase in muscle lactate.

The HR determined at the threshold of AT is a commonly used training indicator. The analysis shows that the change in HR value in the preparatory period was not, as expected, statistically significant. Using only the HR value at the AT threshold without proper verification with additional information, i.e. oxygen intake, power measurement or lactate will not indicate the actual picture of changes in the athlete's effort.

It has been emphasised in the literature that proper preparation of the rider for races will be visible primarily in the increase in WR and VO_2 at the AT threshold and in the absence of changes in HR [23]. For practical reasons, due to the ease of measurement, HR is often used to control the intensity of effort during long journeys and exercises. If even very intense short repetitions do not bring HR to HRmax, a better solution will be to use a power meter that shows the intensity of the mechanical work done by the athlete.

In the tested cyclists, the AT threshold shifted towards higher VO_2 from the average value of 3.21 ± 0.38 l/min (42.69 ± 4 ml/kg/min) determined in the first test to 3.42 ± 0.4 l/min (46.00 ± 5.3 ml/kg/min) in the third test. An increase in VO_2 AT means there occurs an increase in energy released from metabolic processes, which should contribute to the possibility of performing more mechanical work. At the beginning of the observation, the threshold power in the tested cyclists was 252 ± 35W (3.37 ± 0.46W/kg), to improve to 281 ± 38W (3.79 ± 0.53W/kg) at the end of the preparatory period. The recorded significant increase in AT power expressed in relative units was additionally affected by a decrease in body weight of cyclists by an average of 0.9 kg in the discussed period. The obtained result is consistent with the power values at the anaerobic threshold in mountain bikers belonging to the National Off-Road Bicycle Association (NORBA), whose determined values were 3.8W +/- 0.3, respectively [24].

Oxygen heart rate in the assessed 3 months of training increased from 20.6 ± 2.74 to 21.8 ± 3.3 ml/ud, which confirms the improvement in the cardiovascular system of the cyclists under study. This means that, at similar heart rate values, amateur cyclists used more oxygen for muscle work after 3 months of training. One of the important analysed indicators proving the effectiveness of the effort was the oxygen power calculated from the ratio of VO_2 to WR. During 3 months of training at the AT level, this indicator decreased significantly from 12.78 ± 0.8 ml/min/W to 12.22 ± 0.7 ml/min/W. Similarly, in the maximum effort, a significant decrease was noted from 11.32 ± 0.8ml/min/W to 10.81 ± 0.8 ml/min/W, which confirmed the lower oxygen intake of cyclists to generate the same power. Based on the assessment of changes in the value of oxygen pulse and oxygen power, it can be concluded that the training used improved the efficiency of oxygen mechanisms and reduced the energy cost of exercise.

Conclusions

WR, HR and VO_2 are the most frequently registered parameters in laboratory tests conducted on cyclists. A parameter that has been underrated so far is VO_2/WR. As part of the cyclist training, you can improve, among others, the riding technique or position on the bike and it is possible that the effect of these changes will be a reduction in the "unnecessary" work of muscles that consume oxygen. If a good athlete achieves better results in competitions, and in laboratory tests the basic indicators, i.e. VO_{2max} and VE_{max} do not show any improvement, it indicates the need to determine the VO_2/WR indicator, which may show a real picture of the changes taking place.

The training programme implemented by the surveyed cyclists during the preparatory period resulted in a shift in the AT threshold towards a higher % VO_{2max} and a higher WR value as well as a reduction in the aerobic cost of effort, i.e. improving exercise efficiency. VO_{2max} did not change due to training. It can, therefore, be concluded that in Polish amateur cyclists with extensive training experience in assessing training progress, it is important to analyse two physical performance indicators, i.e.

the AT and VO_2/WR threshold, to prove the effectiveness of effort.

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