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ANAEROBIC CAPACITY OF AMATEUR MOUNTAIN BIKERS DURING THE FIRST HALF OF THE COMPETITION SEASON

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AUTHORS: Zarzeczny R.[1], Podleśny M.[2], Polak A.[2]

[1] Institute of Physical Culture and Tourism, Jan Długosz Academy in Częstochowa, Poland;
[2] Chair of Physiotherapy Basics, The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland;

Reprint request to:
Ryszard Zarzeczny
Institute of Physical Culture and Tourism
Jan Długosz Academy in Częstochowa
13/15 Armii Krajowej str.
42-200 Częstochowa, Poland
Fax/Phone: (34) 3655 983
e-mail: r.zarzeczny@ajd.czest.pl

ABSTRACT: Sustained aerobic exercise not only affects the rate of force development but also decreases peak power development. The aim of this study was to investigate whether anaerobic power of amateur mountain bikers changes during the first half of the competition season. Eight trained cyclists (mean ± SE: age: 22.0 ±0.5 years; height: 174.6 ± 0.9 cm; weight: 70.7 ± 2.6 kg) were subjected to an ergocycle incremental exercise test and to the Wingate test on two occasions: before, and in the middle of the season. After the incremental exercise test the excess post-exercise oxygen consumption was measured during 5-min recovery. Blood lactate concentration was measured in the 4th min after the Wingate test. Maximum oxygen uptake increased from 60.0 ± 1.5 $ml \cdot min^{-1} \cdot kg^{-1}$ at the beginning of the season to 65.2 ± 1.4 $ml \cdot min^{-1} \cdot kg^{-1}$ ($P<0.05$) in the season. Neither of the mechanical variables of the Wingate test nor excess post-exercise oxygen consumption values were significantly different in these two measurements. However, blood lactate concentration was significantly higher ($P<0.001$) in season (11.0 ± 0.5 mM) than before the season (8.6 ± 0.4 mM). It is concluded that: 1) despite the increase of cyclists' maximum oxygen uptake during the competition season their anaerobic power did not change; 2) blood lactate concentration measured at the 4th min after the Wingate test does not properly reflect training-induced changes in energy metabolism.

KEY WORDS: anaerobic power, concurrent training, lactate, competition season, mountain biking

INTRODUCTION

Mountain biking is a popular form of recreational activity as well as a competitive sport. In 1996 one of its events – cross-country circuit racing – was included as an official sport in the Olympic Games. Since that time we have observed a growing interest of sport scientists in this subject; however, physiological data regarding mountain biking are still scarce.

As can be observed in other sports, a typical mountain biking training programme is based on the periodization system, i.e. on the division of the entire programme time (usually a year-long plan called a macrocycle) into smaller periods and training units [8]. Traditionally the macrocycles are divided into two major parts: the preparatory (pre-season) period for more generalized and preliminary work, and the second, competition (in-season) period for more specific work and competitions. In addition, a third and the shortest period called the transition or off-season period is set aside for active recovery and rehabilitation [19]. It is worth emphasizing that training sessions during a competition period usually closely mimic priority race characteristics.

Cross-country events are conducted at high intensities. Impellizzeri et al. [17] reported that during cross-country circuit races 18% of the total competition time is spent at exercise intensity below the aerobic threshold (lactate threshold 1), 51% between aerobic and anaerobic thresholds, and 31% above the anaerobic threshold (lactate threshold 2). On the other hand, Stapelfeldt et al. [30] found that 39% of total race time is spent at exercise intensity below the aerobic threshold, 19% between aerobic and anaerobic thresholds, 20% between the anaerobic threshold and maximum oxygen consumption ($\dot{V}O_2max$), and 22% above $\dot{V}O_2max$. The results of these studies indicate that mountain biking requires from the competitors high levels of maximal aerobic and anaerobic capacities for optimal performance. However, there are still insufficient scientific data to assess the impact of aerobic and anaerobic metabolism on cross-country off-road performance. In fact, it has been shown that in high-level off-road cyclists aerobic fitness explains only 40% of the variance in performance [15], which suggests that other factors should be taken into consideration.

Over the last years investigations regarding off-road cyclists have focused mainly on their endurance indices. Now it is well established that aerobic capacity indicators, especially when normalized to body mass, play a significant role in determining mountain biking performance [15,16,23]. Less is known about the anaerobic components requirement in successful competitive off-road cycling, although the importance of high power and anaerobic capacity has been suggested [1,14,17,30].

Many researchers have reported difficulty in simultaneous development of aerobic and anaerobic energy systems during the training process [11,24,32]. Moreover, results of the research investigating the physiological effects of concurrent strength (power) and endurance training are also equivocal. Some studies have shown that concurrent training inhibits the development of strength and power but does not affect the development of aerobic fitness when compared with either mode of training alone [4,13,22,29]. Other studies have shown that concurrent training has no inhibitory effect on the development of strength or endurance [9,20]. Finally, there are studies which demonstrate a positive effect of concurrent training on muscle strength [6] or maximal aerobic capacity [7]. To date there is no clear answer to this problem.

The aim of this study was to investigate whether anaerobic capacity of amateur mountain bikers changes during the first half of the competition season. We chose the competition period because of the fact that in this part of the macrocycle off-road cyclists should already present an optimal performance ability, and any possible physiological changes should be representative of combined aerobic and anaerobic efforts made by mountain bikers during this training period.

MATERIALS AND METHODS

Subjects. A group of 8 young male, regional-class cross-country mountain bikers (mean±SE – age: 22.0 ± 0.6 years; body height: 174.6 ± 1.1 cm; training experience: 4.1 ± 0.4 years) participated in the study. The subjects' characteristics are shown in Table 1. All subjects were healthy and non smokers; none was under pharmacological or special dietetic treatment. Informed consent was obtained from all the subjects after explanation of the nature and risks involved in participation in the experiments. The experiment conformed to internationally accepted policy statements regarding the use of human subjects and was approved by the Ethics Committee at the Academy of Physical Education in Katowice.

Protocol

At the beginning of the season (April) as well as after 10 weeks (in the middle of the season; July), the subjects performed two tests: a graded, incremental exercise test on an electrodynamically braked ergocycle (Excalibur, Lode, Holland), and the Wingate test on a mechanically braked ergocycle (874E, Monark, Sweden). Before the tests body composition was measured using a bioimpedance analyser (InBody 220, Biospace, Korea). All tests were performed in random order at similar times in the morning on separate days at least 2 h after a light meal. The interval between the tests was 3 days. The subjects were instructed not to engage in strenuous activity during the day before an exercise test.

The incremental exercise test served for the determination of maximum oxygen uptake ($\dot{V}O_2max$) and excess post-exercise oxygen consumption (EPOC). The test started with exercise at 0 W and was increased by 40 W every 3rd min, until volitional exhaustion. This exercise test applied in our investigation was similar to the tests used by other authors in studies on off-road cyclists [1,16]. During the test as well as for 5 min after its termination oxygen consumption was measured and recorded breath-by-breath using a gas analyser (Cortex Metalyzer 3B, Germany).

The Wingate test was conducted according to the widely accepted recommendations for standardization [18]. The Wingate test session started with a standardized warm up of 5 min cycling at 50 W including two sprints, each lasting 3 s. After a 10-min rest the subjects started on a given signal (from a stationary start) to pedal as fast as possible. A resistance corresponding to 7.5% of the body mass was applied. During the test using a computer program (MCE v 5.1, JBA, Poland) the following indices were measured: the maximal power output (P_{max}), mean power output (P_{mean}), total anaerobic work (W_{tot}), time for power output to peak (TP_{max}) and fatigue index (FI). Moreover, at rest as well as in the 4th min after the Wingate test, blood samples (0.1 ml) were drawn from the fingertip for lactate concentration. Blood lactate was measured enzymatically using spectrophotometric (Shimadzu, type UV-1201, Japan) assays according to the method described by Bergmeyer [3]. All chemicals were obtained from Sigma-Aldrich Corporation (St. Louis, Mo, USA).

In-season training

In the investigated period each subject followed his own specific training plan. The subjects were training 4-6 times per week, with at least 1 day of active recovery, and on average once a week they participated in a competition. The main goal of the first four weeks was to improve the endurance. The subjects performed mainly long lasting (up to 5.5 h), low-to-moderate intensity workouts (60-80% HR_{max}) with only several high intensity (80-89% HR_{max}) intervals followed by easy spinning. Most of the workouts were done on a road bike with optimal cadence for each subject. In this period of time, the subjects started to take part in cross-country events where rides exceeded three hours. The goal of the next four weeks of the training (week 5-8) was to improve strength and power. The workouts were also characterized by a large volume; however, they included 10-s uphill sprints, 3-4 min climbs (90% HR_{max} and above) and 10-30 min of rides with high intensity (80-89% HR_{max}). The competition rides lasted from 1.5 to 4 hours. During the last 2 weeks (weeks 9-10) the training sessions aimed to maintain already possessed motor skills and consisted of time trials, intervals, sprints and uphill cycling. The typical microcycle was as follows: competition, active recovery, hard workout, hard workout, active recovery, short (20-45 min) workout with racing intensity which was followed by light cycling exercise with the heart rate up to 120 beats$\cdot$min^{-1}, competition. Generally, during the investigated period of 10 weeks the subjects covered on average a distance of (±SE) 261.9 ± 23.5 km·week^{-1} (range 200-320 km·week^{-1}) and spent 568.4 ± 44.9 min·week^{-1} (range: 440-680 min·week^{-1}) riding the bicycle.

Statistics

For each investigated parameter, data normality was verified using a Kolmogorov-Smirnov test with a Lilliefors correction. Next, the results were subjected to one-way repeated measures analysis of variance (ANOVA) followed by the Newman-Keuls' post-hoc test. The relationship between the investigated parameters was assessed by Pearson's product moment correlation coefficient. All calculations were made using the commercial statistical computer program STATISTICA 7.0 (StatSoft, Poland). The level of $P<0.05$ was considered significant. All data are presented as mean ± standard error (SE).

RESULTS

In the middle of the season lean body mass (LBM) of the investigated subjects was increased ($P<0.05$) and fat mass was decreased ($P<0.01$) compared to the values obtained before the season (Table 1). However, during this time period body mass did not change significantly.

Maximum oxygen uptake ($\dot{V}O_2max$) expressed in absolute values as well as in relation to body mass was higher ($P<0.01$ and $P<0.05$, respectively) in season than before the season (Table 1). On the other hand, when $\dot{V}O_2max$ values were expressed in relation to LBM there was no significant difference between these two measurements. Moreover, 5-min excess post-exercise oxygen consumption (EPOC) was also similar pre- and in season.

There was no training effect in absolute Wingate test indices and the values normalized to body mass (Table 1). However, normalization of such data to LBM revealed a significant decrease of P_{mean} ($P<0.05$) and W_{tot} ($P<0.05$) after 10 weeks of the season.

Pre- and in-season values of resting blood lactate concentration (LA) were similar but at the 4th min after the Wingate test LA was significantly higher ($P<0.001$) in season than in pre-season measurement (Figure 1).

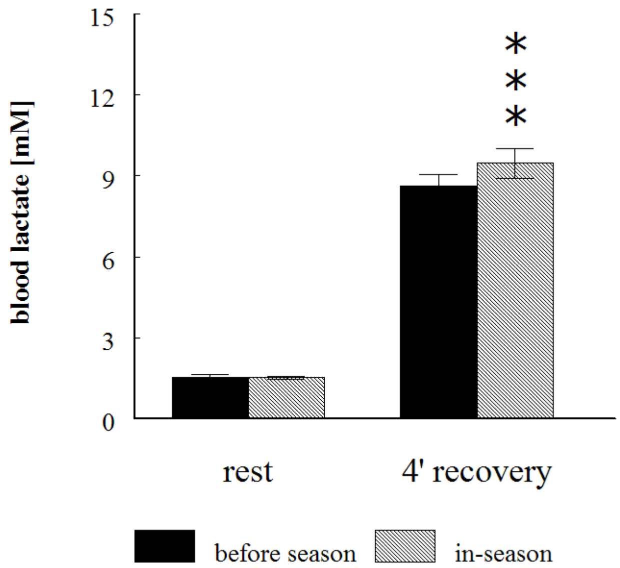

FIG. 1. BLOOD LACTATE CONCENTRATION BEFORE AND IN THE 4TH MIN AFTER THE WINGATE TEST AT THE BEGINNING (BEFORE) AND IN THE MIDDLE OF THE SEASON (IN SEASON)
Note: *** - P<0.001.

TABLE 1. SOMATIC AND PHYSIOLOGICAL CHARACTERISTICS OF THE INVESTIGATED SUBJECTS AS WELL AS MEAN VALUES OF MECHANICAL VARIABLES OBTAINED DURING THE WINGATE TEST (MEAN±SE).

variable	before season	in-season	P
body mass [kg]	70.3 ± 2.9	70.5 ± 3.0	n.s.
LBM [kg]	61.1 ± 1.7	62.9 ± 1.9	P<0.05
fat mass [kg]	9.3 ± 1.3	7.6 ± 1.4	P<0.01
$\dot{V}O_2max$ [l·min^{-1}]	4.2 ± 0.1	4.6 ± 0.1	P<0.01
$\dot{V}O_2max$ [l·min^{-1}·kg^{-1} b.m.]	60.0 ± 1.7	65.2 ± 1.6	P<0.05
$\dot{V}O_2max$ [l·min^{-1}·kg^{-1} LBM]	68.9 ± 1.7	72.7 ± 1.3	n.s.
EPOC [l·5min^{-1}]	8.4 ± 0.5	8.2 ± 0.2	n.s.
P_{max} [W]	827.0 ± 34.1	826.6 ± 31.0	n.s.
P_{max} [W·kg^{-1} b.m]	11.77 ± 0.21	11.75 ± 0.19	n.s.
P_{max} [W·kg^{-1} LBM]	13.52 ± 0.24	13.13 ± 0.27	n.s.
P_{mean} [W]	665.6 ± 30.5	640.1 ± 18.7	n.s.
P_{mean} [W·kg^{-1} b.m.]	9.46 ± 0.15	9.11 ± 0.16	n.s.
P_{mean} [W·kg^{-1} LBM]	10.87 ± 0.24	10.17 ± 0.12	P<0.05
W_{tot} [J]	19973.5 ± 914.7	19202.9 ± 564.8	n.s.
W_{tot} [J·kg^{-1} b.m.]	283.89 ± 4.53	273.44 ± 4.74	n.s.
W_{tot} [J·kg^{-1} LBM]	326.32 ± 7.11	305.23 ± 3.63	P<0.05
TP_{max} [s]	3.9 ± 0.4	3.6 ± 0.2	n.s.
FI [%]	20.5 ± 0.8	23.8 ± 1.2	n.s.

Note: LBM – lean body mass; VO_2max – maximum oxygen consumption; EPOC – excess post-exercise oxygen consumption; Pmax – maximal power output; Pmean – mean power output; Wtot – total anaerobic work; TPmax – time for power output to peak; FI – fatigue index

TABLE 2. CORRELATION COEFFICIENTS AMONG THE WINGATE TEST INDICES AND POST-EXERCISE BLOOD LACTATE CONCENTRATION, MAXIMUM OXYGEN CONSUMPTION, AND EXCESS POST-EXERCISE OXYGEN CONSUMPTION AT THE BEGINNING (BEFORE) AS WELL AS AFTER 10 WEEKS OF THE SEASON (IN SEASON).

Variable	post-ex LA [mM]		$\dot{V}O_2max$ [l·min^{-1}]		EPOC [l·5min^{-1}]	
	before season	in-season	before season	in-season	before season	in-season
P_{max}	-0.41	-0.32	0.73	0.80	0.75	0.82
[W]	n.s.	n.s.	P<0.05	P<0.05	P<0.05	P<0.05
P_{max}	0.54	0.64	-0.01	-0.27	0.03	-0.07
[W·kg^{-1} b.m.]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
P_{mean}	-0.50	-0.27	0.73	0.75	0.74	0.91
[W]	n.s.	n.s.	P<0.05	P<0.05	P<0.05	P<0.01
P_{mean}	0,25	0.80	0.18	-0.65	0.16	-0.30
[W·kg^{-1} b.m.]	n.s.	P<0.05	n.s.	n.s.	n.s.	n.s.
W_{tot}	-0.50	-0.27	0.73	0.75	0.74	0.91
[J]	n.s.	n.s.	P<0.05	P<0.05	P<0.05	P<0.01
W_{tot}	0.25	0.81	0.18	-0.65	0.16	-0.29
[J·kg^{-1} b.m.]	n.s.	P<0.05	n.s.	n.s.	n.s.	n.s.

Note: post-ex LA – post-exercise blood lactate concentration; VO2max – maximum oxygen consumption; EPOC – excess post-exercise oxygen consumption; Pmax – maximal power output; Pmean – mean power output; Wtot – total anaerobic work

As shown in Table 2, some significant relationships were noted. Absolute $\dot{V}O_2max$ as well as EPOC were positively correlated with absolute values of P_{max}, P_{mean} and W_{tot} in both measurement time points. On the other hand, recovery LA positively correlated with relative values (normalized to body mass) of P_{mean} and W_{tot} only in the middle of the season.

DISCUSSION

Training periodization assumes that during a competitive period the training programme should contain more intensified, specialized exercises of reduced volume, including participation in competition [19]. On the other hand, as stated in the introduction, during cross-country events besides high intensity exercises a large amount of time is also spent at an intensity slightly below the anaerobic threshold [17,30]. The results obtained in this study indicate that during the first half of the competition season the investigated subjects improved their maximal oxygen consumption ($\dot{V}O_2max$), increased their lean body mass and decreased body fat content. These changes are typical for endurance training effects [26]. To some extent our results are contrary to the study by Ronnestad et al. [28], who found that during the 13 weeks of a competition period $\dot{V}O_2max$ did not change in elite road cyclists. This inconsistency may be caused by the different subjects' sport class, cycling specificity (on-road vs off-road cycling) and/or body components changes during this period. In fact, adjustment of $\dot{V}O_2max$ to lean body mass only reveals the maintenance of maximal aerobic power throughout the season.

The anaerobic performance of the investigated subjects was similar to that reported elsewhere and typical of excellent test results for active young men [2,18]. Data comparable to our results were obtained by Tanaka et al. [31] in competitive on-road US cyclists as well as by Rodrigues-Morroyo et al. [27], who found a similar value of peak power output in 15 professional on-road cyclists. However, our results are slightly lower compared to the studies investigating anaerobic performance in mountain bikers. Baron [1] using a series of 10-s isokinetic cycling tests noted a peak power output of 14.9 W·kg^{-1} in a group of national- and international-level off-road cyclists. A similar value of maximal power output (14.2 W·kg^{-1}) was reported by Impellizeri and Marcora [14] in six national-level mountain bikers. These discrepancies may be caused by different fitness levels of the investigated subjects and/or the different testing procedure and equipment.

During the first half of the competition season, the absolute indices of anaerobic capacity of the investigated mountain bikers did not change significantly even though their $\dot{V}O_2max$ increased. This finding is in agreement with the results obtained by Helgerud et al. [12]. Among possible mechanisms most often cited in the literature which may be responsible for such an effect one can mention: overtraining, conflicting molecular and physiological adaptations, glycogen depletion, endocrine changes and muscular or neural adaptations [11, 24,32]. The results obtained in our study do not allow one to make an unequivocal conclusion regarding the potential mechanism(s) responsible for a lack of changes in Wingate test indices. However, some speculations can be made. It seems unlikely that this effect may be due to overtraining (since an increase in $\dot{V}O_2max$ was noted) or glycogen depletion and endocrine changes into a more catabolic profile (since an increase in LBM was noted). Coffey and Hawley [5] suggested that concurrent training provides conflicting stimuli for muscle cells due to divergent molecular signalling pathways so the skeletal muscle can only adapt to an aerobic or hypertrophic phenotype. This hypothesis cannot be a full explanation of our results since an increase in LBM was noted (because only lower body cycle training was performed, it is likely that the observed changes in lean body mass occurred in the muscles engaged in the training exercises). On the other hand, although hypertrophy strongly correlates with the muscle ability for force development, the muscle power also relates to the velocity of muscle contraction. The study by Häkkinen et al. [10] showed that during 21 weeks of concurrent endurance and strength training despite the increase in muscle cross-sectional area as well as in maximal isometric force, the rate of force development (RFD) did not change. These authors suggested that concurrent training may lead to interference in explosive strength development mediated in part by the limitations of rapid voluntary neural activation of the trained muscles. Finally, it cannot be excluded that as a result of endurance training the myofibre contractile properties may be modified, i.e. decreased maximum shortening velocity of type II fibres and reduced peak tension development in all muscle fibre types [32], which in consequence might lead to diminished indices of mean power output and total anaerobic work normalized to lean body mass as observed in our study.

Although the anaerobic performance of investigated mountain bikers was not significantly changed during the first half of the season, surprisingly the lactate concentration measured in the 4th minute of recovery was significantly higher in season compared with the pre-season values. This finding could suggest that anaerobic glycolysis was even more involved in the energy production during the in-season all-out exercise; however, the results of Wingate test indices indicate something quite opposite. Beneke et al. [2] estimated that during the Wingate test the contribution of energy systems is as follows: aerobic system 18.6%, phosphagen system 31.3%, and lactic acid system 50.3%. Significant correlations found in our study among $\dot{V}O_2$max and Wingate test indices confirm this notion and an increase in maximum oxygen uptake measured in the middle of the season suggests that aerobic energy production was enhanced in our subjects. On the other hand, the capacity of the phosphagen system seems to be comparable between the two investigated time points since post-exercise oxygen consumption was not significantly different [33]. Taking into consideration a lack of changes in anaerobic performance indices and even slightly diminished mean power output and total anaerobic work normalized to LBM, it seems unlikely that the lactic acid system contributes to higher energy production during the in-season Wingate test. Instead, the higher post-exercise blood lactate concentration noted in the middle of the season can be explained by the adaptive responses to endurance training. There is no doubt that muscle lactate concentration may be used for quantitative estimation of anaerobic energy production. However, the blood lactate concentration is a resultant of lactate efflux from the muscle as well as the rate of lactate degradation in liver and non-acting muscles. It has been shown that during the post-exercise period peak blood lactate concentration occurs earlier in endurance fit subjects and they are able to remove lactate from the blood much faster than untrained subjects [33]. Considering these facts, we may speculate that the higher in-season blood lactate concentration noted in our study occurred as a result of increase in lactate transport capacity [21]. This notion can be partly supported by findings of significant positive correlations between blood lactate and mean relative power output and relative total anaerobic work during the in-season but not in the pre-season test. Similar results were found by Lutosławska et al. [25] in elite wrestlers during an annual training cycle. In that study, it was shown that blood lactate concentration measured in the 3rd min after the Wingate test strongly correlated with the relative mean power output only in the competitive period and not in other phases of the training cycle. Since in that study athletes' $\dot{V}O_2$max was not measured, these authors suggested that this effect may be caused by a specific, high-intensity exercise training programme administered in wrestlers during the competitive period.

CONCLUSIONS

In conclusion, during the first half of the mountain bikers' competition season applying a concurrent high- and low-intensity exercise training programme does not change the absolute values of anaerobic power although the maximum oxygen consumption increases. The significantly lower mid-season values of mean anaerobic power and total anaerobic work normalized to lean body mass obtained in this study may also indicate a need for reconstruction of training load structure. In addition, comparisons of training-induced changes of recovery blood lactate concentration after the Wingate test in off-road cyclists should be made with caution since only in the middle of the competition season does blood lactate reflect the involvement of anaerobic metabolism in energy production.

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