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DIFFERENCES IN THE DIRECTION OF EFFORT ADAPTATION BETWEEN MOUNTAIN BIKERS AND ROAD CYCLISTS

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ABSTRACT
Purpose. Different forms of cycling require the use of different abilities and skills. The aim of this paper was to attempt to identify differences in the directions and dynamics of the body's adaption to training in road (ROAD) and mountain (MTB) cyclists. **Methods.** Research was performed on a group of competitive road (n = 25) and mountain (n = 25) cyclists, mean age 16.96 ± 0.78 years presenting maximal oxygen uptake values of 4.45 ± 0.47 L/min^{-1}. Body composition and physiological and biochemical parameters at rest, during exercise, and during restitution (cool down) were determined. Exercise was performed on a cycle ergometer in the form of a progressive load test. Analysis of the results included cluster analysis and basic statistical methods. **Results.** Cluster analysis indicated that the amount of work performed during the progressive load test was a universal indicator of physical fitness. The level of base excess (BE) in the 3rd min of restitution had a large influence on the remaining parameters in both groups. Training adaptation in MTB were manifested through increased values of maximum heart rate, blood oxygen saturation, oxygen partial pressure, and lactate and BE levels in the blood, as well as a reduction in blood pH and body mass. Conversely, in ROAD, adaptation to effort was evidenced by increased maximum values of oxygen uptake, minute ventilation, cardiac output and the rate of carbon dioxide elimination as well as an increase in hematocrit count and lean body mass. **Conclusions.** Adaptation to training by road cyclists is primarily evident in the development of aerobic capacity. Mountain biking induces adaptive changes in the development of anaerobic capacity by increasing the buffer capacity of the blood and muscles, as well as the development of the oxygen transportation system.

Key words: road cycling, mountain biking (MTB), effort adaptation, physical ability

Introduction

Road cycling competitions are commonly held as single or multi-stage races. Examples of the latter include the Tour de France, which lasts 21 days (~100 hours of exercise) and is performed over a distance of over 3500 km [1]. Road cycling competition demands prolonged effort while forcing competitors to perform at high intensity levels – upwards of 90% of maximum oxygen uptake ($\dot{V}O_2max$) – well above the anaerobic threshold [1]. This finds road cyclists to be characterised by impressive aerobic capacity, reaching maximum aerobic power levels of 370–570 W, maximal oxygen uptake of 4.4–6.4 L min^{-1} and aerobic power at the onset of blood lactate accumulation (OBLA) at 300–500 W [2].

As a result, training in road cycling is based mainly on the development of power and aerobic capacity. In order to develop oxygen capacity, the continuous training is commonly used. It employs exercise performed at average intensity (~60% $\dot{V}O_2max$) for long duration (up to 6 h). Although a road race is mostly performed at constant speed, cyclists often perform 20–70 accelerations during a race at levels above maximum aerobic power [3] whose energy cost is covered via the glycolytic and phosphogenic pathways. Hence, road cycling training also integrates interval and variable training to further improve aerobic capacity and glycolytic capacity as well as develop anaerobic performance.

Mountain bike races are usually performed on natural terrain and rely on overcoming obstacles [4]. This form of cycling competition is performed at high intensity for the majority of a race, some of which last up to two hours. Impellizzeri et al. [5] analysed the work intensity during a race, finding mean heart rate (HR) values of 171 beats min^{-1} (~90% HRmax). Frequent uphill runs and accelerations also require high anaerobic fitness, with the glycolytic and phosphogenic pathways used to meet the required energy demand, causing significant concentrations of lactate in the blood (10–11 mmol L^{-1} during the first 45 minutes of a race) [6]. This makes the buffer capacity of muscle and blood an important determinant in mountain biking performance.

Furthermore, mountain bikers are also characterised by high levels of aerobic capacity, with $\dot{V}O_2max$ values of 72.1 ± 7.4 mL kg^{-1} min^{-1} [7] and aerobic power at OBLA at 366–417 W [8]. However, mountain biking training is much more diverse than that in road cycling, where repetitive training, among others, is used to develop the ability to perform in conditions of alternating phosphogenic and glycolytic pathway use [4]. However, in order to develop glycolytic power and capacity, variable and interval training is also used (as in road cycling).

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In order to better understand the differences between road and mountain cyclists' conditioning, the aim of the present study was to determine the directions and dynamics of adaptation to training by analysing differences in body composition and physiological and biochemical parameters at rest, during exercise (progressive load test) and during restitution (cool down).

Material and methods

The study involved fifty men (*N* = 50) engaged in road (*n* = 25) and mountain cycling (*n* = 25) with 2–5 years of competitive riding experience (championship winners and national team members in their respective categories). The age of participants was between 16–18 years (mean age 16.96 ± 0.78 years). Mean body mass was 68.21 ± 6.71 kg, mean body height 178.44 ± 6.41 cm. Later testing found the participants to present maximum oxygen uptake values of 4.45 ± 0.47 L min^{-1}, or 65.88 ± 6.56 mL kg^{-1} min^{-1} relative to body mass, indicating the high physical fitness of the participants.

The study was approved by the Human Research Ethics Committee at the University of Physical Education in Wrocław, Poland. The participants (or guardian, in the case of minors) signed an informed consent form which outlined the study's aims and procedure.

The subjects were asked to refrain from heavy exercise 24 hours before measurement taking as well as to not eat earlier than 3–4 hours before the actual test.

At rest, the participants were measured for body mass (m) by a WPT-200 (Radwag, Poland) medical scale, body height (h) with an anthropometer (GPM, Switzerland) and resting blood pressure (RRsp); blood pressure over 150/90 mmHg resulted in exclusion from further participation in the study.

Body composition was assessed by a 6100/XL analyser (Futrex, England), measuring body water (Water%) and fat percentage (Fat%), body fat (Fatkg) and fat free body mass (FFMkg) expressed in kilograms, and body water content expressed in litres (WaterL).

Acid-base balance was measured by collecting 80 µl of arterial blood from the fingertip into heparin tubes and immediately examined in a blood gas analyser (model 248, Bayer, USA), determining -log [H^+] (pHsp), partial oxygen pressure (pO_2sp), base excess (BEsp) and blood oxygen saturation (O_2SATsp). Peripheral blood morphology was determined by drawing capillary blood into EDTA tubes and stirring the sample for 2 min. The samples were then entered into an ABX Micros 16 OT (Horiba, USA) haematological analyser for hematocrit (HCTsp) count. A hematocrit count over 50% disqualified a participant from the study. In addition, blood lactate (LAsp) levels were determined by taking 10 µl samples of capillary blood from the fingertip with Dr. Lange LKM 140 test vials (Hach-Lange, Germany) and analysed on a LP 400 spectrophotometer (Hach-Lange, Germany).

An exercise test with progressive load was then administered to the participants on an Excalibur Sport cycle ergometer (Lode, Netherlands). The ergometer was calibrated before each test as well as individually adjusted for each participant. The test began with a load of 50 W, increased by 50 W every 3 min. The subjects were instructed to maintain a cadence of no less than 60 rpm. The test was performed until exhaustion or when an increase in load did not result in increased oxygen consumption, after which the participants continued to pedal with no load for 5 min as restitution (cool down).

The cycle ergometer was connected to a computer that recorded power output, heart rate, time and speed allowing the total work (Wz) done during the test to be calculated. Heart rate (HR) was measured with a S810 heart rate monitor (Polar, Finland).

Respiratory variables were assessed with a Quark metabolic cart (Cosmed, Italy). Measurement of exhaled air began 2 min before the start of the progressive load test and continued for 5 min after it was completed. The metabolic cart was calibrated with atmospheric air and reference gases before each trial. Variables that were recorded included: maximal oxygen uptake ($\dot{V}O_2max$) and maximum oxygen uptake relative to body mass ($\dot{V}O_2max\ kg^{-1}$), maximum rate of carbon dioxide elimination ($\dot{V}CO_2max$), maximum oxygen content (FeO_2max) and carbon dioxide ($FeCO_2max$) in exhaled air, maximum ventilation per minute ($\dot{V}Emax$), maximum respiratory rate (RQmax) and maximum cardiac output (Qmax).

The recorded values were averaged over 30-s periods and cardiac output was then estimated [9]. At the 3rd min of restitution, systolic (RRs3min) and diastolic (RRr3min) blood pressure was measured in addition to the above-mentioned parameters of acid-base balance and blood morphology (a suffix of *3min* denotes that they were measured during restitution).

In total, 26 physiological parameters and five somatic variables were analysed. Basic statistics of the parameters, including arithmetic means, standard deviations and minimum and maximum values, were calculated. The Student's *t* test for independent groups was used to calculate the significance of differences between the mean values of the parameters of the road and mountain cyclists.

An additional step included cluster analysis in order to classify the tested parameters and better indicate the differences between the two groups. This method groups a set of variables into subsets (clusters), where parameters located in one cluster are more closely related, in a certain sense, to each other than to those in other clusters or located further away. The clusters are plotted on a dendogram, creating a hierarchy of clusters that merge with each other at certain distances. The larger the Euclidean distance (abscissa) of a cluster or individual parameter, the greater the influence the parameter or parameters have on the others. All statistical calculations were performed using Statistica v. 10.0 software (Statsoft, USA).

Results

The road cyclists were characterised by higher values of all the analysed physiological parameters than the mountain bikers except for $\dot{V}O_2$max kg^{-1}. However, most of the differences were not statistically significant except for $\dot{V}O_2$max, Wz, $\dot{V}$Emax, $\dot{V}CO_2$max, and Qmax (Tab. 1).

Biochemical parameters were found to be very similar in both groups, although there was a slight trend of exhibiting higher values was observed among the mountain bikers. However, most differences were also found to be statistically insignificant. Significant differences between the groups were found only among pH3min, BE3min and LA3min (Tab. 2).

Analysis of the somatic parameters found mountain bikers characterised by lower mass and body height and, consequently, less lean body mass and body fat as well as lower total water content. Significant differences were recorded for FFMkg and Fatkg as well as WaterL (Tab. 3).

Cluster analysis of the two groups' physiological and somatic characteristics found that three parameters in the mountain bike cyclist group (MTB) and four in the road cyclist group (ROAD) deserved attention (Figs. 1 and 2). However, in both groups, the last or one of the last clusters containing all the other parameters was the amount of work done in the progressive load test (Wz).

Among mountain bikers, maximum heart rate was found to be at a greater Euclidean distance than in road cyclists. The obvious relationship between maximum heart rate (HRmax), maximum lung ventilation ($\dot{V}$Emax) and systolic blood pressure (RRs3min) in both groups bound these parameters into a single cluster. However, less clear is the relationship among diastolic blood pressure (RRr3min) and two other clusters it is connected with containing additional biochemical, physiological and constitutional parameters.

$\dot{V}O_2$max, expressed both in relative and absolute terms, had no decisive influence on the other parameters (small Euclidean distance). However, in MTB, maximal oxygen uptake relative to body mass ($\dot{V}O_2$max kg^{-1}) is farther on the abscissa when compared with road cyclists. Furthermore, BE3min was clustered in both groups, underpinning the importance of this parameter.

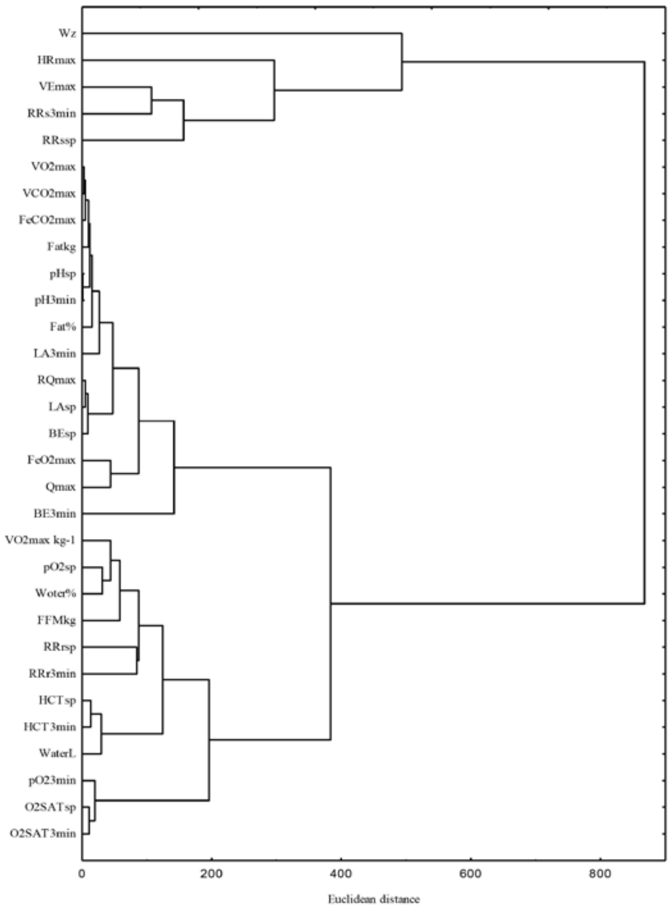

Figure 2. Cluster analysis of the measured variables in the group of road cyclists (ROAD); dendogram depicting the weighted connections by their Euclidean distances

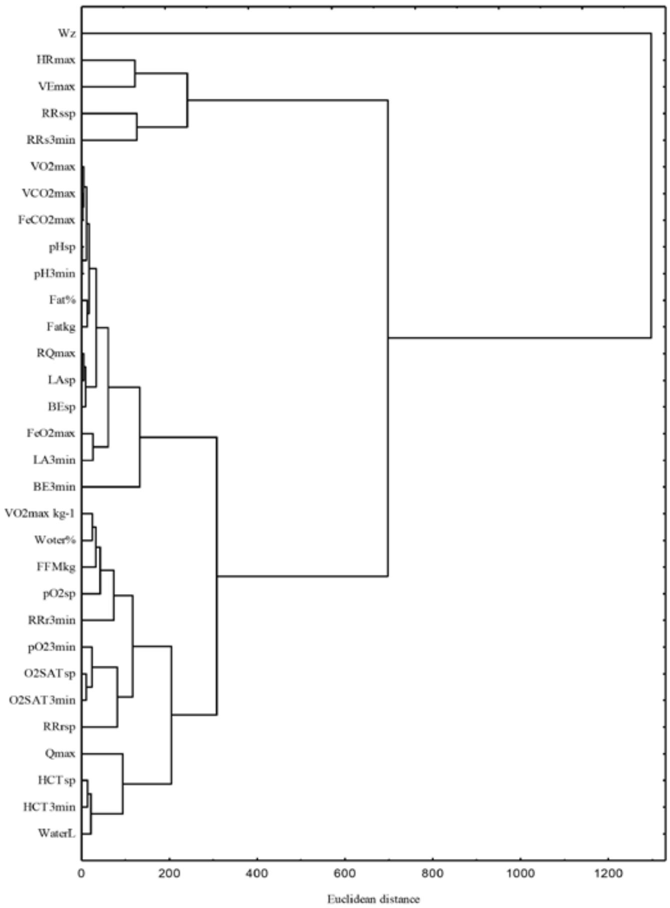

Figure 1. Cluster analysis of the measured variables in the group of mountain bike cyclists (MTB); dendogram depicting the weighted connections by their Euclidean distances

Table 1. The significance of differences among the analysed physiological parameters of mountain bike (MTB) and road (ROAD) cyclists

Parameter	MTB	ROAD	*t*
Wz [kJ]	249.92 ± 50.39	354.88 ± 25.1	–9.32**
$\dot{V}O_2max$ [L min^{-1}]	4.26 ± 0.49	4.64 ± 0.38	–3.10*
$\dot{V}O_2max$ kg^{-1} [mL kg^{-1} min^{-1}]	66.03 ± 7.53	65.73 ± 5.58	0.16
$\dot{V}Emax$ [L min^{-1}]	154.32 ± 18.44	181.32 ± 16.32	–5.48**
$\dot{V}CO_2max$ [L min^{-1}]	4.73 ± 0.52	5.45 ± 0.44	–5.28**
HRmax [bpm min^{-1}]	194.24 ± 9.29	196.8 ± 7.04	–1.10
Qmax [L min^{-1}]	26.5 ± 3.12	28.9 ± 2.05	–3.21*
RQmax	1.64 ± 0.16	1.66 ± 0.13	–0.61
FeO_2max [%]	18.3 ± 0.71	18.44 ± 0.44	–0.83
$FeCO_2max$ [%]	5.38 ± 0.48	5.49 ± 0.49	–0.78
RRssp [mmHg]	125.8 ± 13.05	132.6 ± 11.38	–1.96
RRrsp [mmHg]	77.0 ± 9.35	81.0 ± 7.64	–1.66
RRs3min [mmHg]	147.4 ± 18.04	154.4 ± 15.02	–1.49
RRr3min [mmHg]	70.8 ± 14.41	68.0 ± 13.23	0.72

* $p \leq 0.05$, ** $p \leq 0.001$

Table 2. The significance of differences among acid-base balance, lactate concentration and hematocrit count of mountain bike (MTB) and road (ROAD) cyclists

Parameter	MTB	ROAD	*t*
pHsp	7.41 ± 0.02	7.41 ± 0.02	0.10
pH3min	7.2 ± 0.05	7.16 ± 0.04	3.00*
pO_2sp [mmHg]	70.02 ± 5.42	70.05 ± 5.55	–0.02
pO_23min [mmHg]	95.67 ± 4.27	95.52 ± 4.85	0.11
O_2SATsp [%]	94.0 ± 1.35	93.97 ± 1.52	0.06
$O_2SAT3min$ [%]	95.78 ± 0.72	95.38 ± 0.75	1.92
BEsp [mmol L^{-1}]	–0.04 ± 1.28	0.37 ± 1.53	–1.03
BE3min [mmol L^{-1}]	–14.4 ± 2.39	–16.41 ± 1.76	3.38*
HCTsp [%]	46.05 ± 2.52	45.92 ± 1.83	0.21
HCT3min [%]	48.57 ± 2.67	48.51 ± 2.27	0.09
LAsp [mmol L^{-1}]	0.63 ± 0.29	0.75 ± 0.3	–1.43
LA3min [mmol L^{-1}]	12.09 ± 2.36	13.5 ± 1.43	–2.56*

* $p \leq 0.05$, ** $p \leq 0.001$

Table 3. The significance of differences among the somatic variables of mountain bike (MTB) and road (ROAD) cyclists

Parameter	MTB	ROAD	*t*
m [kg]	64.84 ± 5.79	71.58 ± 5.89	–4.08**
h [cm]	175.6 ± 6.1	181.28 ± 5.5	–3.47*
Fat% [%]	8.66 ± 2.14	9.41 ± 2.66	–1.09
Fatkg [kg]	5.67 ± 1.71	6.86 ± 2.33	–2.06*
FFMkg [kg]	59.16 ± 4.68	65.15 ± 4.26	–4.74**
WaterL [L]	43.43 ± 3.46	47.86 ± 3.18	–4.71**
Water% [%]	67.03 ± 1.48	66.53 ± 1.78	1.07

* $p \leq 0.05$, ** $p \leq 0.001$

In the ROAD group, HCT, Water% and Qmax were found to have a significant impact on the other parameters (large Euclidean distance). In MTB, cluster analysis indicated that blood oxygen saturation (O_2SATsp) and its partial pressure in the 3rd minute of restitution (pO_23min) have a significant impact on the other parameters.

Discussion

Cluster analysis found that the amount of work done during the progressive load test was the last or one of the last clusters containing all the other parameters. This indicates that the work performed during an ergometric test can be used as a universal measure of exercise capacity and a key indicator of performance in mountain biking and road cycling. This can also make it a worthwhile tool in objectively assessing training by measuring improved work efficiency, understood as a reduction in energy cost and physiological work (evidenced by a decrease in submaximal values of $\dot{V}O_2$, HR, $\dot{V}E$ and post-exercise lactate concentration), as performance in cycling is largely determined by the cost-effectiveness of work performed at a submaximal intensity [10–11].

Another parameter that was found to play an important role in mountain biking was maximum heart rate, as evidenced by its greater influence on other variables than in the road group. Its increase is evident of adaptation to anaerobic effort, which is especially dominate in cross-country racing [5]. Road cyclists, on the other hand, feature lower maximum heart rate values, primarily through the use of long-duration training, stimulating the parasympathetic branch of the autonomic nervous system [12].

Additional training effects in both road and MTB cyclists were observed during the exercise test, where increased oxygen demand and an increased rate of carbon dioxide elimination produced during the oxidation of energy substrates were found to provoke increased minute ventilation, heart rate (via decreased parasympathetic nervous system activity and increased sympathetic activity) and systolic blood pressure [13], as was evidenced by the linking of these parameters into a single cluster in both groups.

In both research groups, diastolic blood pressure decreased relative to resting values (6.2 mmHg in the MTB group and 13 mmHg in the road group). Although diastolic blood pressure during exercise may show a slight increase, no change or even a decrease, Cornelissen and Fagard [14], after a meta-analysis of the available literature, indicated that endurance training reduces average resting blood pressure. Therefore, the post-workout reduction in diastolic blood pressure found in the present study is believed to be largely the effect of cycling training.

Furthermore, diastolic blood pressure was found to combine two clusters of various biochemical, physiological and constitutional variables into one.

In the group of MTB riders, diastolic blood pressure (both at rest and at the 3rd minute of restitution) was combined with HCTsp, HCT3min, WaterL (one group of variables) and pO2sp, Water%, FFMkg and $\dot{V}O_2max\ kg^{-1}$ (the second group of variables). The cause of these parameters being clustered together may stem from the fact that water content and blood cell count are known to affect blood pressure through changes in the quantity of plasma and blood viscosity [15].

The MTB cyclists had less body mass and were shorter than road cyclists. They also had featured significantly less lean body mass (MTB: 59.16 ± 4.68 kg versus ROAD: 65.15 ± 4.26 kg, $p \leq 0.05$) and fatty tissue (MTB: 5.67 ± 1.71 kg versus ROAD: 6.86 ± 2.33 kg, $p \leq 0.001$) and less total body water content (MTB: 43.43 ± 3.46 L versus ROAD: 47.86 ± 3.18 L, $p \leq 0.001$). These results are in line with those by other authors such as Penteado et al. [16]. Furthermore, Lee et al. [17] also confirmed mountain bikers are characterised by lower body mass (65.3 ± 6.5 kg, $p = 0.01$) and fatty tissue (sum of seven skin-folds: 33.9 ± 5.7 mm, $p = 0.01$) than road cyclists (74.7 ± 3.8 kg and 44.5 ± 10.8 mm, $p = 0.01$, respectively). Furthermore, Lucía et al. [1] confirmed that competitors specializing in individual time trials on flat terrain are generally taller and heavier than those who specialize in mountain riding. However, they indicated no statistically significant differences in the percentage of body fat in MTB or road cyclists.

These differences in the somatic features of cyclists specializing in different types of riding can be explained by the specificity of the sport and the body's adaptation to training. Success in road cycling is known to be determined mainly by aerobic fitness and the ability to generate and maintain high performance throughout an entire race [2]. Training programmes designed to develop maximum power during cycling result in increased muscle mass, although the development of aerobic metabolism favours a shift toward oxidation of free fatty acids [4] and can cause an increase in muscle triglyceride levels [18]. In contrast, performance in mountain biking requires both strong aerobic and anaerobic fitness, as frequent uphill biking and accelerations rely on energy from the glycolytic and phosphogenic pathways and can lead to significant concentrations of lactate in the blood [6]. As a result, repetition, interval and variable training methods are used by this group in order to maximize aerobic and anaerobic abilities. These forms of training lead to further reductions in body mass, which can also contribute to a reduction of aerodynamic drag and rolling resistance, thus having a major impact on competitive success [19–20].

Other parameters of interest in the MTB group were blood oxygen saturation (both at rest and during restitution) and partial oxygen pressure in the 3rd min of restitution, which were both grouped over a large Euclidean distance. Mean blood oxygen saturation in the 3rd minute of restitution and partial oxygen pressure in the blood were higher in the MTB group (95.78% and 95.67 mmHg, respectively) than in the group of road cyclists (95.38% and 95.52 mmHg, respectively). This may have come about due to increased oxygen saturation and energy without significant increases in haemoglobin concentration and red blood cell count (possibly with changes in erythrocytic indices, although this parameter was not tested). This notion was confirmed by Mørkeber et al. [21], who demonstrated that haemoglobin concentration (Hb) and hematocrit count (HCT) decrease under the influence of aerobic training. They found that, during the off-season, Hb and HCT in elite cyclists were 15 g dL^{-1} and 43.2%, respectively, while during the competitive season they fell to 14.1 g dL^{-1} (Hb) and 40.9% (HCT).

This was attributed to an increase in plasma, where, during exercise, blood volume decreases due to a loss of water as a result of thermoregulation function, and to maintain blood oxygen capacity by reducing glycogen levels. A reduction of plasma volume during exercise has also been linked to intercellular and extracellular fluid shifts [4, 15].

The importance of developing aerobic capacity among road cyclists was seen by the large Euclidean distances of maximum cardiac output, hematocrit count and total body water content, indicating a number of cardiovascular adaptations in this group. The first of these being, namely, an increase in blood density combined with an increase in the amount of the morphological elements of the blood. This factor is believed to contribute to achieving high performance in endurance sports [15]. Secondly, endurance efforts cause an increase in stroke volume and, consequently, an increase in cardiac output, which together with the morphological changes in the blood, further improve aerobic capacity [1, 2, 22].

It is interesting that $\dot{V}O_2max$, expressed in both relative and absolute terms, was not influenced as strongly by the other parameters (based on the small Euclidean distance), even though it is traditionally considered to be one of the most important determinants of cycling performance. This may be explained by the fact that while maximal oxygen uptake efficiency improves the supply of oxygen to the mitochondria, it does not address the efficiency of cellular metabolism [8]. This indicates that this is just one of many parameters that can be used for evaluating performance in cycling and may in fact better serve in the selection of athletes who already are successfully competitive by predicting their development, and not by strictly assessing the effectiveness of a training programme [4].

Also worthy of attention is the use of absolute or relative $\dot{V}O_2max$ values when selecting cyclists to perform in various cycling competitions. Researchers have noted that $\dot{V}O_2max$ relative to body mass is more useful in assessing the fitness of MTB cyclists [6, 11, 23]. In the present study, average absolute maximum oxygen uptake was higher among road cyclists than mountain bikers (4.64 ± 0.38 L min^{-1} versus 4.26 ± 0.49 L min^{-1}, respectively). However, after calculating oxygen consumption relative to body mass, the opposite was found, with MTB cyclists showing higher values (MTB: 66.03 ± 7.53 mL kg^{-1} min^{-1} versus ROAD: 65.73 ± 5.58 mL kg^{-1} min^{-1}).

Tolerance to acidity is the ability of muscles to perform contractions with high concentrations of lactate and hydrogen ions [10]. In mountain biking, this parameter is of particular interest as riders are provided with rest when going downhill after intensive uphill climbs [11], underpinning the interval nature of this kind of effort. The adaptation of the body to increased metabolic acidosis occurs through increased buffer capacity of blood and muscle [24–26] and, as post-exertion BE partially describes the buffering capacity of the blood, explains the link of these two factors in both groups and indicating their importance (higher in MTB group).

Furthermore, the road cyclists were characterised by higher values of Wz, $\dot{V}Emax$, $\dot{V}CO_2max$ ($p \leq 0.001$), $\dot{V}O_2max$ and Qmax ($p \leq 0.05$) than MTB. This suggests that training adaptation in road cycling primarily occurs in the respiratory tract (increased $\dot{V}Emax$, $\dot{V}CO_2max$ and $\dot{V}O_2max$) and the circulatory system (increase in Qmax), as other authors also reported an increase in maximal respiratory values under the influence of training in a group of elite cyclists [1, 8, 22].

Among the statistically significant ($p \leq 0.05$) differences in the biochemical parameters between both MTB and ROAD, higher concentrations of lactate and consequently a higher base excess along with lower blood pH values were found in road cyclists. Contradictory results were obtained by Lucía et al. [23], who compared riders specialising in individual time trials (ITT) with those specialising in mountain stages (C). They found that the C riders featured higher average pH values, maximum concentration of lactate and bicarbonate concentration in venous blood, while the ITT group achieved greater absolute power output. Furthermore, other researchers have also noted the significant impact of mountain biking training on the buffer capacity of the blood and muscles and anaerobic capacity, which include LAmax and post-exercise BE and pH values in the blood and muscle [4, 6, 11]. The differences in these test results may stem from differences in training, diet, motivation to perform at maximum effort during an exercise test or a combination of all these variables. These aspects, which were not analysed in the present study, should be included in future research on training adaptation.

Conclusions

Adaptation to training among road cyclists is expressed through increased aerobic capacity and an increase in lean body mass.

Mountain biking induces adaptive changes in the direction of development of anaerobic capacity by increasing the buffer capacity of the blood and muscles, as well as the development of the system transporting oxygen from the lungs to the tissues. This discipline also promotes changes in body composition leaning towards lower body mass and reduced body fat.

The amount of work done in a progressive exercise test and the concentration of base excess in the blood in the third minute of restitution after maximum effort are useful indicators in monitoring changes in physical fitness of road cyclists and mountain bikers.

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