MORPH-PHYSIOLOGICAL SIMILARITIES BETWEEN ROAD CYCLISTS AND MOUNTAIN BIKERS

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ABSTRACT

Purpose: To characterize and compare the anthropometric and physiological variables in Brazilian road cyclists and mountain bikers.

Methods: Seven trained road cyclists (RC), 10 trained mountain bikers (MTB) and 6 untrained road cyclists (UC) were selected to participate of this study. All athletes were submitted to graded exercise test in the cycle simulator, with 90-110 rpm (trained group) and 60-80 rpm (untrained group), initial load of 100 W and 30 W of increment for each 3 min until exhaustion.

Results: The maximum aerobic power output (Wmax) and the peak oxygen consumption (VO2peak) has not presented significant differences between the groups of trained athletes; however, the values are superior to UC. The blood lactate peak concentrations ([lact]peak) were significantly superior in MTB if compared with the RC (12.5 ± 2.6 vs 9.2 ± 1.0 mmol·L⁻¹) (p<0.05). The sub maximal variables do not presented significant differences between the groups except the workload in the lactate thresholds that are smaller in UC.

Conclusion: In general, except for [lact]peak, Brazilian road cyclists present similar morpho-physiological characteristics to mountain bikers.

Keywords: heart rate, lactate threshold, power output, aerobic, anaerobic.

INTRODUCTION

The training programs of high-level athletes are based on the optimization of training workloads, which are mainly determined by the balance between volume and intensity. One of the main purposes of researchers and coaches is the identification of training strategies that induce substantial physiological adaptations in athletes, thus maximizing individual performance for a specific competitive setting. The discrimination of determinant physiological variables of performance in laboratory as well as in the field is a reference for training workloads prescription and control. In road cycling, the physiological demands during competitions are related according to the event contested, in particular 3-week tour races (i.e. Tour de France, Vuelta a España and Giro d’Italia). These competitions are disputed in road terrains and usually involve different events (1, 2): 1) flat stages where athletes cycle at high speeds in large groups (~ 200 km); 2) individual time trials in prologue (5-10 km); 3) individ-
ual and team time trials (~ 40-60 km) and 4) mountain stages with several hills along approximately 200 km. The physiological demands of professional road cycling competitions suggest that aerobic metabolism is principally involved and the overall participation of high level intensity is considerably lower (3).

In contrast, the cross-country (XC) modality in mountain bike is generally disputed in just one day. This kind of competition is performed in off road circuits consisting of a definite number laps, where all participants start together in a mass group. The athletes can be ridden in single tracks on various types of terrain with many difficulties and several hills. The physiological demands of professional off-road cycling competitions suggest that XC races require high aerobic power during approximately all events (4). In addition, isometric contractions in superior members are used extensively in shock absorption during XC. The event duration can be of approximately 2.3 h. for men and from 1 h. and 45 min. to 2 h. and 25 min. for women (5). Despite the fact that XC competitions are disputed under quite different environments, it still presents some similarities to road cycling. Due to event durations and the characteristics of training sessions, both modalities involve great participation of athlete's aerobic power and capacity, leading to the interest on comparative studies between these modalities. In one of the few studies, Wilber et al. (6) compared the physiological characteristics of professional, North American, high-level road cyclists and mountain bikers, and reported that road cyclists attained higher peak power outputs ($W_{\text{max}}$) during graded exercise tests, both in absolute terms as corrected to body mass. Additionally, road cyclists presented higher (absolute and relative) power output related to the lactate threshold (LL) compared to mountain bikers. On the other hand, Lee et al. (7) observed that Australian national and international level off-road cyclists presented higher $W_{\text{max}}$ and LL intensity relative to body mass than road cyclists. Thus, the conflicting results and the lack of additional evidence in the literature justify further investigations on comparative characteristics of these athletes. Therefore, the purpose of this study was to characterize and compare the morphophysiological variables of Brazilian road cyclists and off-road cyclists.

**METHODS**

The participants of this study were divided into three groups: 1) seven trained road cyclists (RC); 2) ten trained mountain bikers (MTB); The trained athletes were participating in State and National level competitions at the beginning of this study; 3) six untrained cyclists (UC), who occasionally cycled for recreation roads and trails, and/or abstained from competitions for at least two years. The subjects signed an informed consent form, with the experimental procedures previously approved by the Institutional Review Board (number – 017/05 – Florianópolis – Brazil).

The anthropometric evaluation was performed considering the height (stadiometer – Sonny”), body mass (Digital weighing scales – Toledo”) and skinfold measures (Skinfold caliper
The triceps, sub-scacular and abdominal skin folds were obtained and summed, and the percentage of body fat was estimated using Lohmann's equation (8).

In sequence, participants underwent a graded exercise test, performed on the athlete's own bicycle attached to the cycle simulator (CompuTrainer, Seattle, WA). They were warmed up for 8 minutes (50 W), with subsequent cycle simulator calibration in accordance with the manufacturer's recommended procedures. The test was initiated with a stage at 100 W, with 30 W increments at each 3 min, up to exhaustion. During the entire experiment, the trained athletes maintained a pedal cadence between 90-110 revolutions per minute (rpm), and the untrained group between 80-80 rpm. The inability to maintain pedal frequency within these ranges, despite verbal encouragement, was the criteria used for the test interruption in both groups.

When the 3 min stage was not completed, the Wmax was determined according to the equation of Kulers et al., (9):

\[
W_{\text{max}} = Wf + (t/180 \times 30)
\]

Where \(Wf\) is the power output of the last stage, \(t\) is time in seconds of the incomplete stage, 180 are the time in seconds for each stage, and 30 W is the constant increment of power output.

The heart rate was recorded using a Polar* monitor (S610i). The gas exchange variables were recorded at 20 s intervals, using a mask connected to an open circuit gas analyzer KB1C (Imbrasport®, IMBRAMED) through which individuals ventilated during the entire test. The peak oxygen consumption (VO₂peak) was considered as the highest value of oxygen consumption reached during the last stage of the incremental test.

At the end of each stage, the blood lactate concentrations ([La]) were obtained from 25 μl samples of arterialized blood, collected from the earlobe of each individual, which was previously hyperemized with Finalgon*, and were immediately analyzed using an enzymatic technique (YSI 1500 Sport; Yellow Springs Instruments, Yellow Springs, OH), which was calibrated in accordance with the manufacturer's recommended procedures. From blood lactate concentration, two thresholds were determined: the first lactate threshold (LT1) was identified as the lowest lactate equivalent ([La]/W) and for the determination of the second lactate threshold (LT2), a fixed value of 1.5 mmol · l⁻¹ was added to the concentration obtained at the lowest equivalent (10).

**Statistical Analysis**

Data were described as mean and standard deviation. A repeated measures analysis of variance (ANOVA) was used for comparisons among the groups, followed by Tukey post hoc test, for the identification of specific differences, except for the [La] and training volume analysis, which were compared using the Kruskal-Wallis test, due to the lack of Gaussian distribution of the data. For the association among variables the product moment Pearson correlation was used. The level of significance was set at \(P < 0.05\) for all statistical analysis.

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### Table 1 - Characteristics of Mountain Bikers (MTB), Road Cyclists (RC) and Untrained Cyclists (UC)

<table>
<thead>
<tr>
<th></th>
<th>MTB</th>
<th>RC</th>
<th>UC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>27.1 ± 4</td>
<td>25.3 ± 3</td>
<td>29.5 ± 6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>72.0 ± 10</td>
<td>70.9 ± 10</td>
<td>72.8 ± 10</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>175.2 ± 1.2</td>
<td>175.4 ± 1.5</td>
<td>170.8 ± 1.4</td>
</tr>
<tr>
<td>BF (%)</td>
<td>8.9 ± 0.9</td>
<td>9.4 ± 0.3</td>
<td>11.9 ± 2.3</td>
</tr>
<tr>
<td>HBF (mm)</td>
<td>21.3 ± 0.3</td>
<td>27.3 ± 0.7</td>
<td>32.5 ± 2.0</td>
</tr>
</tbody>
</table>

*Significant difference of MTB (P < 0.05)

### Table 2 - Maximal Aerobic Variables Obtained During the Graded Exercise Test in Different Groups: Mountain Bikers (MTB), Road Cyclists (RC) and Untrained Cyclists (UC)

<table>
<thead>
<tr>
<th></th>
<th>MTB</th>
<th>RC</th>
<th>UC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wmax (W)</td>
<td>333 ± 23.7</td>
<td>335 ± 22.9</td>
<td>227 ± 17.3</td>
</tr>
<tr>
<td>Vmax (kg · m · s⁻¹)</td>
<td>5.0 ± 0.2</td>
<td>4.8 ± 0.4</td>
<td>3.8 ± 0.3</td>
</tr>
<tr>
<td>V0₂peak (l · min⁻¹)</td>
<td>4.6 ± 0.7</td>
<td>4.4 ± 0.3</td>
<td>3.6 ± 0.2</td>
</tr>
<tr>
<td>V0₂peak (mm · kg⁻¹ · min⁻¹)</td>
<td>68.7 ± 3.3</td>
<td>64.3 ± 3.1</td>
<td>51.8 ± 6.0</td>
</tr>
<tr>
<td>Hmax (l · mmHg⁻¹)</td>
<td>194 ± 5</td>
<td>189 ± 5</td>
<td>185 ± 6</td>
</tr>
</tbody>
</table>

*Significant difference between MTB and UC (P < 0.05)
### TABLE 3 - SUB-MAXIMAL AEROBIC VARIABLES OBTAINED AT THE GRADED EXERCISE TEST IN DIFFERENT GROUPS: MOUNTAIN BIKERS (MTB), TRAINED CYCLISTS (RC) AND UNTRAINED CYCLISTS (UC)

<table>
<thead>
<tr>
<th></th>
<th>MTB</th>
<th>RC</th>
<th>UC</th>
</tr>
</thead>
<tbody>
<tr>
<td>WLT1 (W)</td>
<td>183 ± 22.1</td>
<td>211.4 ± 22.7</td>
<td>155.0 ± 12.9*</td>
</tr>
<tr>
<td>L1 (%Wmax)</td>
<td>50.0 ± 4.2</td>
<td>63.2 ± 6.0</td>
<td>56.2 ± 7.0</td>
</tr>
<tr>
<td>[La] at L1 (mmol • l⁻¹)</td>
<td>0.9 ± 0.2</td>
<td>1.3 ± 0.8</td>
<td>1.6 ± 0.9</td>
</tr>
<tr>
<td>HR at L1 (bpm)</td>
<td>133 ± 13</td>
<td>141 ± 12</td>
<td>133 ± 15</td>
</tr>
<tr>
<td>% HRmax at L1</td>
<td>69.4 ± 6.3</td>
<td>75.2 ± 6.1</td>
<td>72.0 ± 8.0</td>
</tr>
<tr>
<td>WLT2 (W)</td>
<td>256.6 ± 20.0</td>
<td>266.4 ± 15.7</td>
<td>207.5 ± 10.8*</td>
</tr>
<tr>
<td>L2 (%Wmax)</td>
<td>77.2 ± 5.0</td>
<td>79.6 ± 1.3</td>
<td>75.0 ± 4.5</td>
</tr>
<tr>
<td>[La] at L2 (mmol • l⁻¹)</td>
<td>2.4 ± 0.2</td>
<td>2.8 ± 0.8</td>
<td>3.1 ± 0.9</td>
</tr>
<tr>
<td>HR at L2 (bpm)</td>
<td>162 ± 10</td>
<td>162 ± 9</td>
<td>155 ± 14</td>
</tr>
<tr>
<td>% HRmax at L2</td>
<td>84.4 ± 4.5</td>
<td>86.4 ± 3.6</td>
<td>83.8 ± 2.3</td>
</tr>
</tbody>
</table>

* Significant difference between MTB and RC (P < 0.05)

### FIGURE 1 - PEAK BLOOD LACTATE CONCENTRATIONS [La • PEAK] AT THE END OF GRADED EXERCISE TEST IN THE DIFFERENT GROUPS

![Graph showing peak lactate concentrations](image)

### RESULTS

The investigated athletes did not present significant differences in age, weight and height; however, percent of body fat (%BF) and sum of selected skin folds (SSF) presented statistically significant differences when the UC group was compared to MTB (table 1). The Wmax and VO_peak measures obtained during graded exercise test, both defined as absolute and relative body mass values, were not significantly different among the trained athletes group. However, when compared to the UC, the values were significantly higher for the trained athletes (table 2). The maximum heart rate (HRmax) was similar among the groups.

In relation to peak [La], the only significant difference was the higher level of MTB in relation to RC (Fig 1).

All sub maximal variables from the investigated individuals were expressed in relation to the first and second lactate thresholds (table 3).
When compared, no significant differences among the groups of athletes were found. The UC group presented IT1 and IT2 intensity values lower than MTB and RC groups (p < 0.05).

**DISCUSSION**

The morphological variables indicate that the MTB, RC and UC groups present reduced body mass, without a significant difference among them (67.0 ± 6.0; 70.9 ± 7.8; 72.3 ± 3.8 kg; respectively). However, there was a tendency of higher values in UC and lower in MTB. Body mass of MTB group is similar to that reported in the studies of Impellizzeri et al. (4, 11) and Lee et al. (7) with values close to 65 kg. The RC group presented higher body mass when compared to professional road cyclists specialist in mountain stages (62.4 ± 4.4 kg) (12). However, the values are similar to the mountain bikers investigated by Stapelfeldt et al. (13) (69.4 ± 4.7 kg). The RC group also presented distinct values compared to the road cyclists specialist in flat stages 76.2 ± 3.2 kg (12).

The different techniques used to estimate %BF many times make difficult the comparisons with other studies. Significant differences were not found among the athletes of this study in the estimate of %BF and SSF. Wilber et al. (6) did not find significant differences in body composition of North American mountain bikers and road cyclists either. However, Lee et al. (7) compared the body composition of professional athletes, and reported that the %BF of mountain bikers was significantly lower than road cyclists (6.1 ± 1.0 vs 7.9 ± 1.8%). In this regard, some authors suggest that morphological similarities found in road cyclists specialist in mountains and off-road cyclists may be related to the event conditions (4, 7) because athletes compete in terrains with ascents, where body mass, associated to gravity, exerts influence over performance (14). Thus, low body mass and low estimate of fat indexes, observed in the athletes of this study, seem to be related to performance in mountain events in road cycling and XC.

The maximal aerobic variables report that MTB and RC groups present relatively high levels of performance, expressed in values of Wmax (335.0 ± 23.0 W; 330.0 ± 240 W) and VO2peak (4.4 ± 0.31 · min⁻¹; 4.3 ± 0.71 · min⁻¹), respectively; while the UC present moderate level of aerobic fitness. However, these athletes are in lower values compared with the international and professional athletes (6, 12, 13). Lucía et al. (15) compared the physiological differences between professional and elite cyclists.

The results indicate that for both groups, the performance levels were very high – Wmax (466 ± 31 vs 423 ± 32 W) and VO2max (6.1 ± 0.6 vs 4.9 ± 0.41 · min⁻¹) – when compared to the participants in our study. Wilber et al. (6) studied mountain bikers and road cyclists, and the values found for Wmax and VO2max were 420 ± 42 vs 470 ± 35 W, and 4.9 ± 0.4 vs 5.1 ± 0.41 · min⁻¹, respectively. The different protocols used may be difficult the comparisons among the studies and can lead to misleading interpretations. In spite of methodological differences, we believe that the lower levels of aerobic fitness presented by athletes in this study may reflect the characteristics of their training programs, which is believed to be inferior in quality, when compared to professional athletes (16, 17).

The values of relative Wmax and VO2peak obtained by the MTB and RC groups do not presented significant differences, but the UC has inferior as compared for these groups. All these values were below to that recorded in professional road cyclists, between 6.0 and 6.5 W · kg⁻¹ for Wmax, and VO2peak of 70 and 80 ml · kg⁻¹ · min⁻¹ (1, 2); and mountain bikers (6.3 W · kg⁻¹, 74 ml · kg⁻¹ · min⁻¹) (18). Lee et al. (7) demonstrated that the XC athletes attain values of relative Wmax and VO2peak significantly higher than the road cyclists, suggesting that these athletes present more appropriate characteristics to generate high power outputs in relation to their body mass. However, Wilber et al. (6) verified that the road cyclists attained higher Wmax values than off road cyclists, both in the absolute and relative terms. The different findings about the maximal variables are difficult to be interpreted. In the Lee et al. (7) study, it can be noted that, unlike the road cyclists, some participants had their status among the best in the world of XC. The participants in our study were athletes of national level, and their physiological characteristics associated to their training characteristics are inferior to athletes with notability in international level.

The main finding in our study is related to peak [La]. The mountain bikers reached significantly higher values than the UC group (fig. 1). These findings suggest that the XC athletes, due to the specificity of the modality, probably have greater participation of anaerobic metabolism during training and/or competition, which can lead to higher levels of [La] during graded exercise test. Stapelfeldt et al. (13) used portable dynamometers to objectively quantify the intensity of exercise during XC competitions. The results indicate that 42% of the entire time of competition is performed above IT2. In addition, at the start and in ascents, the athletes raise the power output above Wmax reached in laboratory. Therefore, one can infer that the XC competitions, in spite of being predominantly aerobic, require high anaerobic participation. This may tax the anaerobic capacity and lactate tolerance from athletes. Unlike the results of our study, Wilber et al. (6) did not find significant differences in peak [La] in male off-road cyclists and road cyclists (10.4 ± 2.7 vs 11.8 ± 1.7 mmol · l⁻¹). However, there is a tendency for higher peak [La] in road cyclists. The possible explanations may be partially related to the increased recruitment of fast-twitch motor units and the consequent mobilization of anaerobic metabolism at intensities near Wmax, that was higher in road cyclists compared with mountain bikers in that study.

The sub maximal aerobic variables were not significantly different among the trained groups. However, the power output values obtained at IT1 and IT2 were lower for the UC group. This is easily explained by the reduced volume and intensity of training. Nevertheless, the IT1 and IT2 expressed in %HRmax and %Wmax were not different among the trained group and untrained road cyclists, suggesting that the important adaptation to training is associated to changes in the absolute levels of metabolic transitions, concomitant to changes in sub maximal power output and Wmax. According to Noakes et al. (19) Wmax during graded exercise tests is the best predictor of cycling performance, since it combines the movement economy and VO2max.

Wilber et al. (6) reported that off-road cyclists presented lower power output at anaerobic threshold compared with
road cyclists (271 ± 29 vs 321 ± 17 W; 3.8 ± 0.3 vs 4.4 ± 0.3 W · kg⁻¹), respectively. In contrast, Lee et al., (7) found greater values in power output at anaerobic threshold for off-road cyclists, only in relative terms (5.2 ± 0.6 vs 4.7 ± 0.3 W · kg⁻¹), respectively. The present study reported no differences between RC and MTB at lactate thresholds. In this sense, the lack of consensus seems to be related to the competitive level of the studied athletes. The mountain bikers investigated by Lee et al., (7) were probably of higher competitive level than the road cyclists. On the other hand, Wilber et al., (6) emphasizes that their groups were both competitive at international level.

The morphophysiological variables of the present study represent values of some references to predicts performance in competitions and training programs for road cyclists and off-road cyclists. Lucía et al., (20) reported that performance in long time trial competitions during the Tour de France (>50 km distance) is related, at least in part, to the power output that elicits the ventilatory threshold during gradual exercise test. Bentley et al., (21) demonstrated that in sub elite cyclists, the relationship between Wmax and the power output at the VT may change depending on the length of the time trial that is complete.

In XC competitions, the previous model that Wmax, V0₂max metabolic thresholds to predicts performance during time trials road cycling, seem to be similar. Thus, these physiological variables represent more significant when related to body mass. Recently, Impellizzeri et al., (11) reported in Italian off-road cyclists significant correlations between aerobic power and capacity to performance in XC competitions when normalized to body mass. In conclusion, the identification of sub maximal and maximal variables during graded exercise tests seems to be important because they represent references to prescription, control and predicts performance during aerobic exercise. This investigation suggests that the only remarkable difference between MTB and RC is the [La peak] at the end of a graded exercise test. These were not significant differences in the sub maximal and maximal aerobic variables among the trained athletes, both expressed in absolute as in relative body mass terms. As expected, the UC presented lower levels of LT1, LT2 and Wmax when compared with the trained groups. In comparison to international level athletes, the Brazilian road cyclists and off-road cyclists who participate of this study presented lower levels of performance during graded exercise test.

REFERENCES