AEROBIC FITNESS AND AMPLITUDE OF THE EXERCISE INTENSITY DOMAINS DURING CYCLING

EXERCISE AND SPORTS SCIENCES

ORIGINAL ARTICLE

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ABSTRACT

Introduction: The determination of the exercise intensity domains has important implications for the aerobic training prescription and elaboration of experimental designs. Objective: The aim of this study was to analyze the effects of aerobic fitness level on the amplitude of the exercise intensity domains during cycling. Methods: Twelve cyclists (CYC), eleven runners (RUN) and eight untrained subjects (NT) underwent the following protocols on different days: 1) progressive test to determine lactate threshold (LT), maximal oxygen uptake (VO_{2max}) and its corresponding intensity (IVO_{2max}); 2) three constant workload tests until exhaustion at 95, 100 and 110% IVO_{2max} to determine critical power (CP); 3) constant workload tests until exhaustion to determine the highest intensity at which VO_{2max} is reached (I_{sup}). Results: The amplitude of the moderate domain was similar between CYC (52 ± 8%) and RUN (47 ± 4%) and significantly greater in CYC when compared with NT (41 ± 7%). The heavy domain was significantly smaller in CYC (17 ± 6%) when compared with RUN (27 ± 6%) and NT (27 ± 9%). In relation to severe domain, there were no significant differences among CYC (31 ± 7%), RUN (26 ± 5%) and NT (31 ± 7%). Conclusion: It can be concluded that the heavy domain is more sensitive to changes determined by the aerobic fitness level; there is a need hence to observe the training specificity, when high level of physiological adaptation is aimed.

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Keywords: anaerobic threshold, oxygen consumption, aerobic exercise

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INTRODUCTION

Three exercise intensity domains have been identified through the kinetics of the pulmonary oxygen consumption (VO_2) and the response of the blood lactate ([La]) concentration during exercises of constant load, namely: moderate, heavy and severe[1,2]. The moderate domain corresponds to all the exercise intensities which can be performed without alteration of blood lactate concerning the rest values; that is, below the lactate threshold (LT)[1]. The heavy domain starts from the lowest intensity at which blood lactate increases and has as highest threshold the critical power (CP)[2]. The severe domain is characterized for the reach of the maximal oxygen consumption (VO_{2max}), being limited between the CP and the exercise intensity which allows minimal time to VO_{2max} acquisition (i.e., Isup)[3]. The determination of the exercise intnensity domains has important implications in the prescription of aerobic training and design of experimental outlines, since it makes better acute individualization of the physiological responses possible and possibly better correlation between the stress level and expected adaptation[3-5].

Aerobic training determines adaptations both in oxygen central suply and in the capacity of its use, being able to improve physiological indices related to aerobic performance such as the LT, the VO_{2max} and its respective intensity (IVO_{2max}), as well as the economy of movement (EM)[6]. In sedentary or active individuals, the improvement in aerobic performance and physiological indices which predict this performance is evident after aerobic training performed at submaximal intensities[7]. However, additional increase in submaximal aerobic training (greater volume) in highly-trained individuals does not seem to modify aerobic performance in its associated physiological variables (i.e., LT, VO_{2max}, EM)[8]. Moreover, many studies have verified that the lactate response to exercise (i.e., LT) presents higher sensitivity to aerobic training than the variables which may allow increase of Isup, such as the VO_{2max} and kinetics of the oxygen consumption [6,9]. Thus, it is possible to hypothesize that long-term aerobic training (e.g. > 3-5 years), could more expressively modify the moderate domain, when compared with the remaining domains. However, few studies have assessed the exercise intensity domains[10] and, to the present moment, as far as we are concerned, no study has assessed the amplitude of the exercise intensity domains in individuals with different levels of aerobic fitness during cycling.

Ideally, the analysis of the aerobic training effects on performance and the physiological indices should be carried out in a longitudinal manner. However, the duration of the training protocols hardly ever surpasses 20 weeks, being rare to find those which last more than one year. The few which last more than this period end up being characterized as case studies[11]. Alternatively, well-controlled transversal comparisons can let us observe some possible alterations which occur after years of aerobic training. Within this context, the aim of this study was to analyze the effects of the level of aerobic fitness on the amplitude of the exercise intensity domains during cycling. Based on the principle of the training specificity, the analysis of endurance runners during cycling makes it possible to obtain s group with intermediate aerobic fitness among untrained individuals and well-trained cyclists[3,12].

MATERIAL AND METHODS

The samples of this study were composed of male individuals, namely: 12 cyclists (age: 25 ± 5 years; body weight: 67 ± 8 kg; height:

175 ± 5 cm), 11 runners (age: 27 ± 9 years; body weight: 65 ± 6 kg; height: 173 ± 6 cm) and eight untrained ones (age: 24 ± 3 years; body weight: 72 ± 11 kg; height: 175 ± 6 cm). The athletes had at least three years of training in the modality. All the volunteers received information about the experiment's procedures and its implications, and signed a Free and Clarified Consent Form for participation in this study. The protocol of this study was approved by the Ethics Committee in Research of the University where the experiment was held.

Procedimento experimental

Each volunteer visited the laboratory in three phases: 1) an incremental test for determination of the LT, VO_{2max} and IVO_{2max}; 2) three test sessions for determination of the CP parameters; and 3) the third phase involved determination of I_{sup}. The individuals received orientation to come for the tests barefoot, fed and hydrated, and not to perform intense exercise in the last 48 hours. Concerning each volunteer, the tests were performed in the same location and at the same time (± at two o'clock). The tests were performed on a cycle ergometer of mechanical break (Monark, 828E, Sweden). The respiratory variables were measured using a gas analyzer (K4b2, Cosmed, Rome, Italy), collecting data at each breath. The blood samples were analyzed on an electrochemical lactate analyzer (YSL 2300 STAT, Ohio, USA) and the heart rate monitored through a frequency meter (Polar, Kempele, Finland).

Determination of LT, VO_{2max} and IVO_{2max}

The initial load used for the incremental test on a cycle ergometer was 105 W for the cyclists (CYC), 70 W for the runners (RUN) and 35 W for the untrained individuals (NT), with increments of 35 W at every 3 min, until voluntary exhaustion. At the end of each phase the HR and 25 µl of blood from the earlobe were collected, with no pause. The highest VO_2 obtained during 15 s was considered the VO_{2max}. All individuals met at least two out of the three criteria for the VO_{2max}: 1) gas exchange ratio (R) $\geq$ 1.1; 2) HR_{max} at least equal to 90% of the maximum expected for the age; and 3) peak lactate concentration higher than 8 mM[13]. The IVO_{2max} was considered as being the lowest exercise intensity at which the VO_{2max} occurred[14]. The LT was considered as the intensity prior to the increase in lactate concentration above the baseline values. It was determined by two experienced and independent examiners. In case there was disagreement between the examiners, a third one was used as a decision.

Determination of critical power (CP)

The individuals performed three tests of constant load at different intensities (95, 100 and 110% IVO_{2max}) until voluntary exhaustion on different days. The test started with 10 min of warm-up at 50% IVO_{2max} followed by 5 min of recovery. Subsequently, the individuals were told to pedal at the intensity determined until they were not able to maintain the set intensity. The test started with the individuals pedaling with resistance zero, until cadence of 70 rpm was reached; at that point, the pre-set load was imposed and the timer was started. The test ended when the individual was not able to maintain cadence above 67 rpm, after verbal encouragement. During the test, the VO_2 peak (VO_{2max}) was defined as the highest value in 15-second means.

The individual values of power-time limit obtained in the constant load tests were adjusted through the hyperbolic model with two parameters (equation 1) (HILL, 1993), using the non-linear regression procedure in the Microcal Origin software 6.0 (Northampton, MA, USA):

$$\text{tlim} = \text{CTA}.(\text{power} - \text{CP})^{-1}$$

The values were derived for two parameters: CP, which is the assyntote of the ratio and the CTA, defined as the area limited by the delimited by the CP, the x-axis and any other point in the power-time curve. Regressions were also performed using the linear equivalent power-tlim^{-1} and the work-time ratio models. The estimated parameters (CP and CTA) were not significantly different among the three models. Thus, for each participant, the estimated parameter generated using the hyperbolic model with two parameters was sued as measurement criterion (CYC, SEE = 5.3 ± 5.7 and R^2 = 0.98 ± 0.03; RUN, SEE = 4.6 ± 3.1 and R^2 = 0.97 ± 0.02; NT, SEE = 6.0 ± 4.2 and R^2 = 0.98 ± 0.02).

Determination of the highest intensity (Isup)

Subsequently, in order to determine the I_{sup}, linear regression techniques were used to describe the ratio between time to reach the VO_{2max} ($TAVO_{2max}$) and tlim during the prediction loads (95, 100 and 110% IVO_{2max}). Thus, through the $TAVO_{2max}$ expressed as tlim function, it was possible to find the only tlim in which the VO_{2max} was reached at the exhaustion moment ($TAVO_{2max}$=tlim). Therefore, the Isup was estimated using the equation 1, substituting the tlim for the $TAVO_{2máx}$[15]. After the Isup was estimated, at least two maximal exercise tests were performed to really determine it. After 10 minutes of warm-up at 50% of IVO_{2max} and 5 min of recovery, the intensity was adjusted in 100% estimated Isup and the individual was verbally encouraged to maintain the exercise until exhaustion. In the other tests, held on different days, 5% of increase or decrease were applied in the intensity between each test, until the VO_{2max} value was reached or not. In that case, the highest intensity at which the VO2 mean of three consecutive values of 5 s (i.e. 15 s) was higher or equal to the mean less one standard deviation (SD) of VO2max obtained in the incremental test and in the constant load tests (95, 100 and 110% IVO2max) was considered as determination criterion of the Isup. The VO_2 was continuously measured throughout the protocol. The amplitudes of the domains (moderate $\leq$ LT; LT > heavy $\leq$ CP; CP > severe $\leq$ Isup) were expressed as percentage of Isup (VO_2).

Statistical analysis

The data were expressed as mean ± SD. The normality of the variables determined in this study was analyzed by the Shapiro-Wilk test. The analysis of the effects of the aerobic fitness on the submaximal and maximal variables was performed by the analysis of variance one-way ANOVA, complemented by the Scheffé test. The analysis of the effects of the level of aerobic fitness on the amplitude of the exercise domains (%Isup) were performed by the Kruskal-Wallis non-parametric test. In all tests a significance level of $p \leq 0.05$ was adopted.

RESULTS

The maximal values obtained during the incremental test of the CYC, RUN and NT groups are expressed in table 1. The VO_{2max} of the CYC group was significantly higher than in the RUN and NT

Table 1. Mean ± SD values of the variables obtained in the progressive test of the cyclists (CYC), runners (RUN) and untrained (NT) groups.

Variables	CYC (N = 12)	RUN (N = 11)	NT (N = 8)
VO_{2max} ($ml.kg^{-1}.min^{-1}$)	65 ± 7*	55 ± 6†	42 ± 4
IVO_{2max} (W)	348 ± 32*	257 ± 40	220 ± 43
HR_{max} (bpm)	187 ± 6	177 ± 14	187 ± 11
[La]peak (mM)	12 ± 2	9 ± 2•	10 ± 1

* p < 0.05 concerning groups RUN and NT. † p < 0.05 concerning group NT. • p < 0.05 concerning group CYC.

groups ($p < 0.05$). The VO_{2max} of the RUN group was significantly higher than in the NT group ($p < 0.05$). The IVO_{2max} of the CYC group was significantly higher than in the RUN and NT groups ($p < 0.05$). There was no significant difference between the RUN and NT groups ($p > 0.05$). The [La] peak of the RUN group was significantly lower than for the CYC group ($p < 0.05$). There was no significant difference between the CYC and NT groups and RUN and NT groups ($p > 0.05$). The HR_{max} was similar between groups ($p > 0.05$).

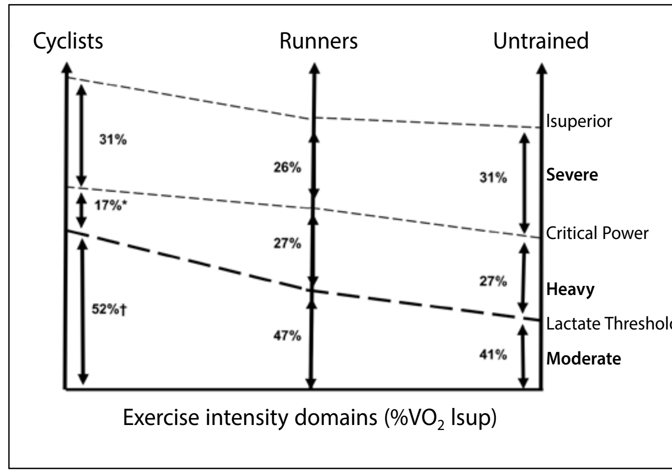
The LT (VO_2 and W) of the CYC group was significantly higher than in the RUN and NT groups ($p < 0.05$). There was no significant difference between the RUN and NT groups ($p > 0.05$). The CP (VO_2 and W) of the CYC group was significantly higher than in the RUN and NT groups ($p < 0.05$). The CP (VO_2 and W) was significantly different between groups RUN and NT ($p < 0.05$). The Isup (VO_2 and W) of the CYC group was significantly higher than in the RUN and NT groups ($p < 0.05$). The Isup (VO_2 and W) of the RUN group was significantly higher than in the NT group ($p < 0.05$) (table 2).

Concerning the amplitude of the intensity domains (relative values – % IsupVO_2), the domain 'moderate' of the group CYC (51.7 ± 7.9%) was significantly higher compared with the NT (41.2 ± 6.8%) (p = 0.0044) and without significant differences concerning the RUN group (46.7 ± 4.2%). No significant difference has been found between NT and RUN. Regarding the heavy domain, the CYC presented significantly smaller amplitude (17.5 ± 3.5%) compared with the RUN (27.1 ± 5.6%) (p = 0.0021) and NT (27.5 ± 9.1%) (p = 0.0034). No significant difference was found between RUN and NT groups. The amplitude of the severe domain was similar between groups (CYC = 30.9 ± 6.5%; RUN = 26.2 ± 5.2%; and NT = 31.3 ± 7.3%) ($p > 0.05$) (figure 1).

Table 2. Mean ± SD values of the oxygen consumption (VO_2) and load (W) corresponding to the lactate threshold (LT), critical power (CP) and highest intensity (Isup) of the cyclists (CYC), runners (RUN) and untrained (NT) groups.

Variables	CYC (N = 12)	RUN (N = 11)	NT (N = 8)
VO_2LT ($ml.kg^{-1}.min^{-1}$)	45 ± 7*	29 ± 4	20 ± 4
LT (W)	219 ± 37*	125 ± 28	87 ± 31
VO_2CP ($ml.kg^{-1}.min^{-1}$)	60 ± 7*	45 ± 4†	33 ± 6
CP (W)	302 ± 33*	222 ± 35†	167 ± 48
VO_2sup ($ml.kg^{-1}.min^{-1}$)	87 ± 10*	61 ± 6†	48 ± 5
Isup (W)	449 ± 34*	319 ± 51†	257 ± 59

* p < 0.05 concerning the RUN and NT groups. † p < 0.05 concerning the NT group.



* p < 0.05 concerning the runners and untrained groups. † p < 0.05 concerning the untrained group.

Figure 1. Amplitude of the moderate, heavy and severe exercise intensity domains for the cyclists (N = 12), runners (N = 11) and untrained (N = 8) groups.

DISCUSSION

As far as we are concerned, this study was pioneering in determining and analyzing the effects of the level of aerobic fitness on the amplitude of the exercise intensity domains during cycling. The main finding of this study was that the intermediate levels of aerobic fitness (i.e.,RUN) are already sufficient to increase the amplitude of the moderate domain during cycling. However, in order to occur decrease of amplitude of the heavy domain, high levels of aerobic fitness and specific training in cycling (i.e.,CYC) seem to be necessary. Finally, the amplitude of the severe domain does not seem to be influenced by the different levels of aerobic fitness.

According to what is classically demonstrated, the CYC group presented higher values of VO_{2max} compared with the RUN and NT groups[3,12]. Moreover, the VO_{2max} of the RUN was significantly higher than of the NT. These data show that although there is transference of the running training effects to cycling (i.e., RUN > NT), very specific adaptations seem to be necessary for the improvement of VO_{2max} in cycling, when the aim is the highest increase as possible of this indice and/or when training is performed by highly- trained athletes (i.e. CYC > RUN). Similar conclusions may be obtained concerning the CP and Isup, which presented the same behavior as VO_{2max}. However, the lactate response to exercise (i.e., LT – VO_2 and W) seems to present a different behavior from the other variables. Although the LT (VO_2 and W) of the CYC had been higher than in the other groups, there was no significant difference between RUN and NT. Thus, for the aerobic indices which prioritarily depend on the peripheral adaptations (i.e., oxidative capacity)[16], the training effects are more specific to the type of trained exercise, and there may not be transferences from one type to another. Regarding the VO_{2max}, CP and Isup, there may be partial transference of the training effects between the exercise types (running to cycling), probably due to the central mechanisms (i.e., oxygen supply) which contribute to the improvement of these indices after training. Similar data were obtained after the longitudinal analysis of the training effects performed by sedentary individuals with duration of 10 weeks[17].

The moderate exercise domain comprises all the exercise intensities which can be performed without alteration of the blood lactate concerning the rest values; that is to say, intensities which are performed until the LT [1]. As initially hypothesized, the CYC presented higher amplitude of this domain compared with NT; however, there was no difference compared with the RUN (figure 1). Thus, when the amplitude of the domains is normalized regarding Isup (%IsupVO_2), there seems to be a partial transference of the training effects from running to cycling.

However, for the heavy domain, the CYC group presented lower amplitude concerning the RUN and NT. The decrease of the heavy domain in the CYC suggests that aerobic training in the long run may improve more the LT than the CP. Caputo and Denadai[18] verified in well-trained cyclists that the CP represents 75%Δ (i.e., 75% of the difference between the LT and VO_{2max}), while in sedentary subjects, Neder *et al.*[10] verified a value of 67%Δ. In the same way, Greco *et al.*[19] found that the CP expressed in %VO_{2max} was similar between cyclists and untrained subjects (91% *versus* 87%, respectively); despite the fact the lactate response (maximal lactate steady state – MLSS), had been significantly different (83% *versus* 77%, respectively). These data altogether show that, similarly to the VO_{2max}, the CP may be less sensitive to the training effects than the lactate response (LT and MLSS). However, this adaptation seems to be dependent on long term specific aerobic training in cycling.

Finally, the severe domain, which comprises all the intensities which obtain the VO_{2max}, seems not to be influenced by the different levels of aerobic fitness. Although the majority of the intensities, and consequently, the shorter times of exercise kept in this domain (i.e., Isup = 2 to 3 min)[3] are predominately aerobic[20], the anaerobic sources of energy also play an important role. This fact can explain, at least partly, the absence of influence of aerobic fitness on the amplitude of the severe domain found in this study.

CONCLUSION

Based on the data obtained in this study, it can be concluded that the lactate response (LT) presents adaptations more specific to the training than the remaining aerobic indices (CP and VO_{2max}). Moreover, the exercise domain 'heavy' is reduced with the increase of aerobic fitness, suggesting hence that the LT is more sensitive to the aerobic training than the CP. However, these adaptations seem to be dependent on specific adaptations in cycling. Therefore, it is necessary that the specificity of the movement principle is respected when a high level of physiological adaptation is expected.

All authors have declared there is not any potential conflict of interests concerning this article.

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