The perceived exertion threshold (PET) corresponds to the critical power and to an indicator of maximal oxygen uptake steady state

Fábio Yuzo Nakamura[1,2,3,4], Antônio Fernando Brunetto[3], Daniel Müller Hirai[3], Bruno Tesini Roseguini[3] and Eduardo Kokubun[2]

ABSTRACT

The perceived exertion has been a target of several investigations, many times with association with objective physiological indicators in exercise. Recently, the identification of the perceived exertion threshold (PET) was proposed in the water running, which presented no difference in relation to the critical velocity. Theoretically, both parameters would be indicators of the maximum steady state of variables such as $\dot{V}O_2$ and blood lactate. The objective of this work was to verify the coincidence between PET, critical power (PCrit) and an indicator of maximum $\dot{V}O_2$ steady state (PCrit') in cycle ergometer. Eight male participants were submitted to progressive effort test in order to determine $\dot{V}O_{2peak}$ (46.7 ± 8.5 ml/kg/min) and to four rectangular tests until exhaustion for the estimation of the critical power model parameters, PET and PCrit'. The hyperbolic relation between mechanical power and time spent for the $\dot{V}O_{2peak}$ to be reached in each test was used for the PCrit' estimation, considered as the asymptote in the power axis, and the portion of the anaerobic work capacity (CTAnaer) depleted up to the establishment of the $\dot{V}O_{2peak}$ (CTAnaer'). In order to identify PET, the straight lines angular coefficients of the perceived exertion in time (ordinate) and the powers used (abscissa) were adjusted to a linear function that provided a point in the power axis in which the perceived exertion would be kept indefinitely stable. The parameters PCrit and CTAnaer were estimated by means of the power-time non-linear equation. In order to compare the estimations of PET, PCrit and PCrit', the analysis of variance ANOVA was employed for repeated measurements, and the associations were established through the Pearson correlation. CTAnaer and CTAnaer' were compared through the *t* test. PET (180 ± 61), PCrit (174 ± 43) and PCrit' (176 ± 48) were not significantly different and the correlations were of 0.92-0.98. CTAnaer' (14,080 ± 5,219 J) was lower than CTAnaer (22,093 ± 9,042 J). One concludes that the PET predicts the intensity of PCrit and PCrit' with accuracy.

Key words: Perceived exertion. Critical power. Maximum $\dot{V}O_2$ steady state.

INTRODUCTION

Recently, it was proposed that the subjective effort perception could be used in the determination of the critical velocity in the water running[1]. It was observed that the perceived exertion (15-points Borg[2] scale) increased linearly during rectangular tests at a rate proportional to the running intensity. By means of linear extrapolation of the relation between velocity and perceived exertion increase rate, it was possible to estimate an intensity in which, theoretically, this psychophysical variable would be kept indefinitely stable. This intensity, called as perceived exertion threshold (PET) was not different from the critical velocity and both presented high correlation. The critical running velocity, derived from the Monod and Scherrer[3] critical power model, corresponds to the intensity of maximum $\dot{V}O_2$[4] and lactate[5] steady state. Therefore, this velocity is considered as an aerobic capacity measurement. Not many investigations searched to combine the critical power model with perceived exertion[6,7].

The perceived exertion seems to result from the integration of a series of afferent information originated from sensorial structures situated at the active skeletal muscles and the cardiorespiratory system[2]. These structures would be primarily stimulated by the metabolic acidosis associated to the drop on the muscular and blood pH[8], mainly because the severe intensities[9] employed in the PET determination would induce a non-steady state of the lactate concentration in the different body compartments. Thus, the efferent neuromotor activity would need to be increased in order to compensate the peripheral fatigue triggered by the contractile failure and to increase the pulmonary ventilation, also modulating the perceived exertion[10]. This compensatory phenomenon may be verified through the increasing electromyographic activity of knee extensor muscles during constant severe workloads in cycle ergometer[11,12]. The hypothesis[1] that the increase on the perceived exertion would be proportional to the depletion of the anaerobic work capacity (CTAnaer) was raised, variable also predicted by the critical power model[3,13], being defined as the energy supply originated from phosphagen supplies and from the anaerobic glycolysis mobilization resulting in lactacidemia. Thus, the perceived exertion would have close relation with the constructs of the critical power model.

Hill and Smith[14] proposed a technique to estimate the intensity associated to the maximum $\dot{V}O_2$ steady state with the adoption of some presuppositions of the model. According to Gaesser and Poole[9], this intensity indicates the transition between heavy and severe effort domains. Hill and Smith[14] submitted subjects to three rectangular tests in cycle ergometer that induced exhaustion between 1-10 minutes. In each test, the time spent for the $\dot{V}O_{2peak}$ to be reached was measured. The power x time relation up to $\dot{V}O_{2peak}$ ($t_{\dot{V}O2peak}$) was adjusted to a hyperbolic function equivalent to the

1. Metabolism, Nutrition and Exercise Research Study Group, Sports and Physical Education Center. Londrina State University – Londrina/PR.
2. Biosciences Institute/Department of Physical Education, São Paulo State University – Rio Claro/SP.
3. Pulmonary Physiotherapy Laboratory – Londrina State University – Londrina/PR.
4. Grupo de Estudo das Adaptações Fisiológicas ao Treinamento (GEAFIT), Centro de Educação Física e Desportos, Universidade Estadual de Londrina.

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Correspondence to: Fábio Yuzo Nakamura, Grupo de Estudo e Pesquisa em Metabolismo, Nutrição e Exercício, Centro de Educação Física e Desportos, Universidade Estadual de Londrina, Rod. Celso Garcia Cid, km 380, Campus Universitário – 86051-990 – Londrina, PR – Brasil. E-mail: fabioy_nakamura@yahoo.com.br

function proposed by Monod and Scherrer[3]. The asymptote of the hyperbola generated would be equivalent to the power in which the time spent for the $\dot{V}O_{2peak}$ to be reached would be infinite. The curvature degree of the hyperbole in joules would be the average amount of aerobic energy required for the $\dot{V}O_{2peak}$ to be reached in each load. This value of mechanical work is below CTAnaer. However, the asymptote of the power x $t_{\dot{V}O2peak}$ relation was not different from the group's critical power (PCrit), on average, defined from the asymptote of the power x time relation until exhaustion. The validity of the equality between PCrit and the maximum $\dot{V}O_2$ steady state directly measured was demonstrated by Poole *et al.*[15,16]. In both studies, in prolonged exercise at PCrit, the stabilization of $\dot{V}O_2$ at around 80% of its maximum value was observed, where with a load increment of only 5%, this variable increased up to reaching $\dot{V}O_{2peak}$, generating exhaustion in a few minutes. Therefore, the technique of Hill and Smith[14] seems to have physiological support.

The hypothesis of this study was that the PET would compose the indirect and alternative measurement of the transition between heavy and severe effort domains[9], once in this adjacent portion between domains, not only physiological variables would present stability along time, but also the own perception of effort that, according to the current models[17], composes a complex and integrated central representation of the several body functions acutely modified by exercise.

The objective of the present study was to enlarge the PET physiological description by extending its application to a type of exercise (cycle ergometer) different from the exercise originally proposed (water running). Moreover, one intended to verify the equivalence of the PET estimated in cycle ergometer, in relation to the PCrit and to the indicator of maximum $\dot{V}O_2$ steady state proposed by Hill and Smith[14].

METHODS

Subjects

Eight male young individuals with 21.4 ± 4.2 years of age, 180.0 ± 5.4 cm of stature and 74.5 ± 4.9 kg of body mass participated in this study. All participants signed the free and informed consent term. The procedures adopted in this investigation were approved by the Researches Ethics Committee – Unesp/Rio Claro.

Test for the $\dot{V}O_{2peak}$ determination in progressive effort test

The progressive effort test was conducted in a *Monark*® cycle ergometer with mechanical resistance. The ventilatory variables were determined with the use of a *VO2000* (Aerosport Inc.). The equipment used for the analysis of the gas exchange was calibrated before each effort tests based on a sample of environment gas (20.9% of O_2 and 0.04% of CO_2) and on a sample from a cylinder with known O_2 (17%) and CO_2 (5%) concentrations. Moreover, the flow of gases to the device was calibrated with a three-liters syringe, according to the manufacturer's standardization. The gas analyzer was adjusted in order to analyze the gases exhaled each three ventilatory incursions. The heart rate (HR) was monitored during the entire test in the beat-to-beat mode by means of a *Polar*® Heart Rate Monitor – model S810i.

The participant remained sitting for three minutes on the cycle ergometer before the test started for the measurement of the HR in rest and ventilatory variables. Later, the participants pedaled for three more minutes with no external resistance. With no interruption, the progressive effort test was conducted with initial load of 20 W and load increments of 20 W per minute until voluntary exhaustion. The participants were verbally encouraged by the investigators. The average of the $\dot{V}O_2$ values reached in the last six measurements previous to exhaustion was considered as the $\dot{V}O_{2peak}$. For the next stages of the study, the confidence interval ($CI_{95\%}$) of the final $\dot{V}O_2$ values was also calculated.

The criterion proposed for the $\dot{V}O_{2peak}$ value to be accepted was that the HR in the last stage of the test would reach the range of ± 10 bpm in relation to the maximum value predicted by the age of each subject, that the respiratory exchange ratio (RER) was above 1.1 and that the subjective reported effort based on the 15-point Borg scale was above 19 at the final moments of the test. The $\dot{V}O_2$ plateau criterion was not included because the individuals presented no visual evidences of stabilization for this variable in the protocol adopted.

Tests for the estimation of PCrit and CTAnaer

Each individual performed four rectangular exercise trials in the *Monark*® cycle ergometer with the objective of estimating the parameters of the critical power model. All participants had been familiarized to the ergometer and to the type of effort in two exhaustive rectangular sessions in days preceding the beginning of the collection of conclusive data. Before each test, a five-minute warm-up exercise with 30-40 W of resistance was performed. After same duration period for recovery and preparation, the test started. A minimum of 24 hours of interval was applied between tests in order for the residual fatigue not affect the next load. The participants were told not to perform intense efforts in days between tests and preferentially not to ingest any type of food two hours before tests. The intensities were individually selected so that the efforts lasted as long as 1-10 minutes[18]. Eventually, some subjects performed loads which duration exceeded 10 minutes. However, none of them lasted longer than 15 minutes or shorter than 1 minute. No information was given to participants with regard to the intensity of loads and expected duration of tests. Due to the relative heterogeneity of the group, the rectangular loads employed presented average power ranging from 160 and 350 W.

The individual data regarding power and time until exhaustion were adapted to the non-linear equation below for the estimation of PCrit and CTAnaer. In previous works[1,19], linear equations arithmetically equivalent were presented for the calculation of the parameters[20]. However, only equation 1 was selected because this equation respects the mathematical rule of power allocation as independent variable and time as dependent variable[21], and this configuration is compatible with the experimental condition adopted in this study.

$$Time = CTAnaer/(power - PCrit) \qquad \text{(equation 1)}$$

Estimation of PCrit' and CTAnaer'

During tests for the estimation of PCrit and CTAnaer, the individuals had their pulmonary gas exchanges monitored in *VO2000*. The calibration procedures of gases concentration and their flow to the device were the same as those adopted for the performance of the progressive effort test. Once again, the equipment was adjusted in order to perform the analyses each three ventilatory incursions. During each one of the exhaustive tests, the time required for the individual to reach $\dot{V}O_{2peak}$ ($t_{\dot{V}O2peak}$) was recorded, which was determined in the progressive effort test. Due to oscillations inherent to the $\dot{V}O_2$ measurement performed within reduced time intervals, the period elapsed until the first moment in which this measurement reached $CI_{95\%}$ of the $\dot{V}O_{2peak}$ was adopted as the time spent until $\dot{V}O_{2peak}$. The criterion adopted was that from five consecutive readings, at least three were within $CI_{95\%}$, established based on the last six $\dot{V}O_2$ measurements of the progressive effort test. The time spent until the first $\dot{V}O_2$ reading in this condition was recorded as $t_{\dot{V}O2peak}$. This tolerance was allowed because the $\dot{V}O_2$ usually reaches asymptotic values – plateau – in severe domain tests just at the moment in which it reaches its maximum value. Thus, it is quite common that some measurements at this region of the $\dot{V}O_2$ kinetic curve oscillate downward, temporarily remaining out of the $CI_{95\%}$. Besides, close to the end of the test, the participants tend to reduce the pedal rotation velocity due to fatigue when the power is momentarily decreased, what may lead to readings below the tolerance interval to consider $\dot{V}O_2$ as the peak value.

The individual data regarding power and $t_{\dot{V}O2peak}$ were adapted to equation 2 below, equivalent to equation 1 for the estimation of PCrit' and CTAnaer'.

$$T_{\dot{V}O2peak} = CTAnaer'/(power – PCrit') \qquad \text{(equation 2)}$$

where PCrit' corresponds to the indicative of maximum $\dot{V}O_2$ steady state and CTAnaer' corresponds to the mechanical work deriving from anaerobic supplies spent until $\dot{V}O_{2peak}$ is reached[14].

Estimation of PET

During the four exhaustive tests, the individuals were instructed to report the perceived exertion according to the 15-points Borg scale each 30 seconds of exercise. The angular coefficient of the regression straight line between time as independent variable and the individual perceived exertion values attributed during each test was determined through linear regression. The angular coefficients of the four straight lines (perceived exertion increase rate) obtained with this procedure were used in order to estimate the parameters of the linear regression straight line in function of the power generated in the four tests. The PET was defined as the intensity corresponding to the intersection point of the regression straight line in the power axis (x), in other words, it would be equivalent to the intensity in which the perceived exertion increase rate would be equal to zero. Figures 2 and 3 exemplify these procedures in a representative individual.

Statistical treatment

Parameters PCrit, PCrit', CTAnaer and CTAnaer' were estimated by equations 1 and 2 by means of nonlinear regression procedures. The comparison between estimations of PCrit, PCrit' and PET was performed through the analysis of variance (ANOVA) for repeated measures. The CTAnaer and CTAnaer' values were compared through a *t*-test for paired samples. The Pearson correlation coefficient was used to verify associations between PCrit, PCrit' and PET estimations. The significance level adopted for all analyses was of $P < 0.05$.

RESULTS

The $\dot{V}O_{2peak}$ reached in the progressive effort test by the sample studied was of 46.7 ± 8.5 ml/kg/min. The rectangular tests used for the prediction of parameters of the critical power model, PCrit', CTAnaer' and PET presented power values equivalent to 216 ± 35 W, 239 ± 40 W, 262 ± 40 W and 288 ± 41 W on average. The respective durations were of 547 ± 121 s, 364 ± 52 s, 263 ± 49 s and 182 ± 35 s.

Figure 1 (upper curve) illustrates the hyperbolic relation between power and time until exhaustion of a representative individual. The same figure (lower curve) represents the relation between power and time spent to reach $\dot{V}O_{2peak}$ in each test. In this individual, a coincidence between asymptotes was observed. In the group as a whole, the behavior was similar, once PCrit and PCrit' were not significantly different ($P > 0.05$) (table 1). The correlation between both parameters was of 0.96. CTAnaer' and CTAnaer were equivalent to 14,080 ± 5,219 and 22,093 ± 9,042 J, respectively.

Figure 2 shows the behavior of the perceived exertion along time during the four rectangular tests of a subject from the sample. One could observe a good linear adjustment of this variable in function of the duration of each test (r^2 between 0.89 and 1.00). In some cases, the visual verification showed that the first perceived exertion value reported did not fit the regression straight line formed by the remaining experimental points. In this case, this value was excluded from the analysis, what generally increased the value of r^2. There were also occasions in which the last points repeated on

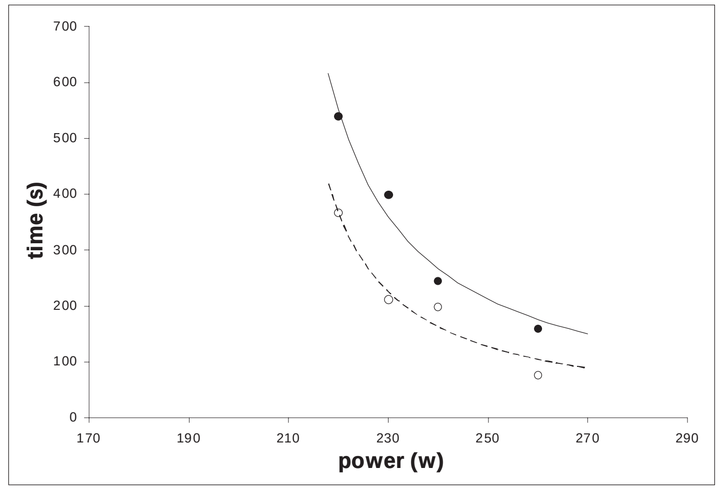

***Fig. 1** – Relation between power and time until exhaustion (full circles and continuous line) and between power and time until $\dot{V}O_{2\,max}$ is reached (empty circles and dotted line) of a representative subject with the same asymptote in axis x for both curves*

TABLE 1
Average values (± SD) of critical, power (PCrit), indicator of maximum $\dot{V}O_2$ steady state and perceived exertion threshold (PET)

PCrit (W)	PCrit' (W)	PET (W)
174 ± 43	176 ± 48	180 ± 61

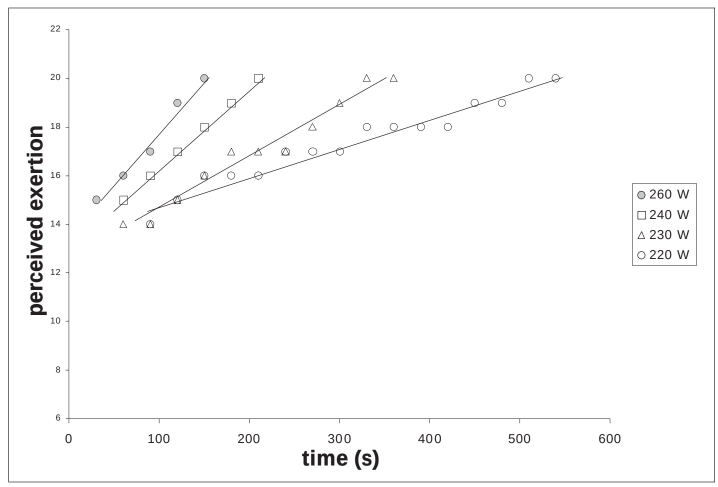

***Fig. 2** – Increase on the perceived exertion along time in exhaustive rectangular tests of a representative subject*

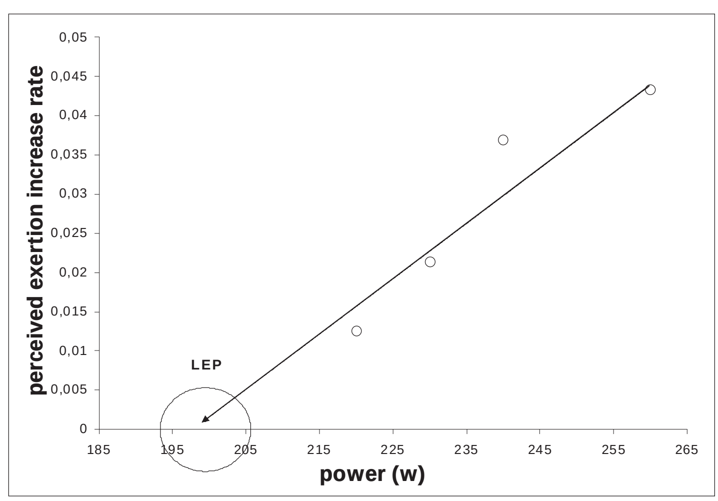

***Fig. 3** – Determination of the perceived exertion threshold (PET) through linear regression between perceived exertion increase rate and power of a representative subject*

the number 20, which is the maximum value of the scale. This usually occurred in the longest tests. These points also weakened the linearity tendency of the rest of the curve. Thus, these values were also excluded in order for the linear portion of the curve to be described with the best adjustment by the regression equation.

The PET calculated as the example of a case shown in figure 3 was not significantly different ($P > 0.05$) from PCrit and PCrit' (table 1). A high correlation between PET and PCrit (r = 0.98) and PCrit' (r = 0.92) was observed.

DISCUSSION

According to Gaesser and Poole[9], three effort domains may be distinguished based on the kinetic behavior of some physiological variables in exercise. The first one, called as moderate, involves the effort intensities that can be supported without induction of the lactic acidosis; therefore below the lactate threshold. In this domain, the $\dot{V}O_2$ presents a mono-exponential increase at the first 180 seconds of rectangular load, reaching steady state after this period. The heavy exercise domain presents the workload in which the balance between lactate production and removal is favorably disposed to the first one as lower limit and the load corresponding to the maximal lactate steady state that is coincident with PCrit as upper limit. In this domain, after the initial 80-110 s of exercise, a low component of the $\dot{V}O_2$ kinetics is superposed to the fast component, causing a delay on its stabilization. This additional oxygen volume consumed in function of time causes loss of linearity of the relation between steady state $\dot{V}O_2$ and the load, observed in the moderated domain. In the third domain, called as severe, there is no stabilization of the $\dot{V}O_2$ neither of the lactate. Both parameters increase inexorably up to the occurrence of exhaustion, when the $\dot{V}O_2$ invariably reaches its maximum value.

In the theoretical model presented by Gaesser and Poole[9], the perceived exertion maximum steady state is not expected to occur at intensity corresponding to the PCrit. However, due to the fact that the perceived exertion is currently understood as a complex and integrated central representation of the several body functions modified by exercise[17], one may infer that its behavior along time resembles that of the lactate and $\dot{V}O_2$ at intensity corresponding to the transition between intense and severe domains. Thus, the main objective of this work was to test this hypothesis directly by means of comparison between PET, PCrit and an indicator of maximum $\dot{V}O_2$ steady state. To our knowledge, this application of perceived exertion through the 15-point Borg scale is original. However, other authors have proposed techniques to estimate indicators of aerobic capacity with the use of effort subjective scales including the adoption of purposes of the critical power model.

Capodaglio and Saibene[6] used 10-point Borg perceived exertion scale – CR10[2] in order to estimate the sustainable mechanical power in daily activities of elderly individuals in cycle ergometer both for upper limbs and for lower limbs. This intensity is below PCrit traditionally estimated based on exhaustive tests in elderly individuals[22,23]. The tests proposed by Capodaglio and Saibene[6] were not conducted until voluntary exhaustion but rather until the moment in which the perception of effort reached the "heavy" level with 5 in the Borg CR10 scale. The values of mechanical work and time until this point in 5-6 tests were adjusted to the work-time linear equation[20]. The inclination of the regression straight line was considered as the supportable intensity for daily activities and corresponded to about 55% of the maximum power reached by lower limbs, being easily maintained for 30 minutes with heart rate of approximately 114 bpm, reduced elevation on the blood lactate (2.2 mM) and concentration near to that associated to the lactate threshold occurrence.

In other work, Garcin *et al.*[7] showed that the perceived exertion reported in the active musculature in the fifth minute of predictive trials of the parameters of the critical power model in cycle ergometer and in knee extension exercises was negatively correlated (r = –0.78 and –0.80) with the logarithm of time until exhaustion. Moreover, it was positively correlated (r = 0.76 and 0.85) with the percentage of PCrit used in the test and with the electromyographic activity at the same collection moment (r = 0.70 and 0.58). Thus, the authors concluded that the perceived exertion at a fixed point (five minutes) of exhaustive tests could be considered as an indicator of aerobic capacity, once it predicts the tolerance to effort, the CTAnaer utilization magnitude and the neuromuscular activation degree related to fatigue.

Finally, Okura and Tanaka[24] also searched to estimate a submaximal indicator of aerobic capacity and the ventilatory threshold by means of a 15-point Borg scale. Subjects from a validation group performed incremental test (90 kgm/min) in mechanical cycle ergometer up to the value of 15 of perceived exertion in the legs was reached in that scale. Along with age, the load of occurrence of value 15, expressed as mlO_2/min, was adjusted to an equation through multiple regression procedure in order to predict the ventilatory threshold. The equation seemed to be satisfactory, once the estimation standard error of the ventilatory threshold estimated in relation to the observed one, in percentage terms, was of only 13.3%. Furthermore, the cross-validation group obtained good prediction indexes of the ventilatory threshold based on the use of the equation proposed. However, it is worth mentioning that this type of procedure for the proposition of predictive equations of aerobic capacity indicatives based on the perceived exertion is protocol-dependent; in other words, the use of a test protocol different from the protocol originally proposed may generate estimations distant from the actual estimations.

None of the studies mentioned above had as objective the estimation of the exercise intensity corresponding to the maximum $\dot{V}O_2$ steady state based on the perceived exertion that indicates the transition of effort domains. Moreover, in none of them, a data collection protocol regarding the follow-up of the perceived exertion x time curve behavior was adopted, once the authors used either the fixed submaximal perceived effort to finalize the test or the fixed time with no exhaustion. The authors did not attribute a well-defined physiological or psychological meaning to the perceived exertion that would allow the establishment of a causal relation with other relevant variables in the exercise.

However, according to the hypotheses raised in our previous study[1], the estimation of PET is based on the presupposition that the increase on the perceived exertion would occur at a rate depending on the H^+ accumulation as result of the CTAnaer utilization. This peripheral disturbance would generate a necessity to increase the afferent stimuli to the active muscles, corroborated by the increase on the electromyographic activity reported in exercise protocols similar to ours[11,12]. Both sources of information (afferent and efferent) would be potential feeders of the perceptive response generation[10]. Therefore, the perceived exertion increase rate equal to zero would be associated to the exercise state in which the anaerobic supplies would not be used, what would coincide with PCrit and with the maximum $\dot{V}O_2$ steady state.

Indeed, the results of this study seem to confirm those hypotheses. The values of PCrit, PCrit' and PET were equal to 174 ± 43, 176 ± 48 and 180 ± 61 W, respectively, and not significantly different ($P > 0.05$). Moreover, the correlations between them were high (r = 0.92 – 0.98). CTAnaer' and CTAnaer were estimated in 14,080 ± 5,219 and 22,093 ± 9,042 J, respectively. The fact that CTAnaer' is significantly smaller than CTAnaer indicates that a portion relatively fixed of the muscular anaerobic supply should be used in order for the $\dot{V}O_{2peak}$ to be reached and that other portion of this supply should be used after reaching $\dot{V}O_{2peak}$, leading to exhaustion. The physiological meaning of this finding is not clear.

According to Hughson *et al.*[25], the "error signal" for the cardiorespiratory system to increase $\dot{V}O_2$ is established by the difference between the actual value and the value required for the maintenance of the metabolic rate fixed by the exercise. In severe exercise, these values are never equal. A fast adjustment on the $\dot{V}O_2$ is desirable as the velocity of the O_2 deficit accumulation is minimized, generating lower levels of lactic acid. However, these adjustments are limited by the capacity of the cardiovascular system of redistributing the blood flow fastly and maintaining blood pressure within adequate levels, making the $\dot{V}O_2$ increase kinetics, given by the time constant (τ) to be slower in severe exercises than in moderate intensities[25], above all when close to $\dot{V}O_2$ plateau in severe rectangular tests[26]. Thus, it seems that the increase on rest $\dot{V}O_2$ up to its maximum value in rectangular exercises performed in the severe domain is generated by an "error signal" associated to a fixed anaerobic cost (~ 64% of the CTAnaer). The persistence of the "error signal" leads to the CTAnaer depletion and to the lactate linear increase. Below PCrit, this anaerobic cost is minimized, once in some moment of the exercise, the sign of physiological error seems to be equal to zero, allowing the stabilization of the physiological and psychological variables indicative of internal work of the organism.

The rectangular tests conducted in this study for the estimation of PET, PCrit, PCrit' and the anaerobic variables, generated the individual $\dot{V}O_{2peak}$ values in all cases presented. However, it is worth emphasizing that an individual was excluded from the sample because he was not able to reach values near to $CI_{95\%}$ established in the progressive effort test in none of the exhaustive loads. Thus, one may infer that not all individuals responded to exercise allowing the identification of PCrit' and CTAnaer'. So, we have considered PET as an alternative estimation of the maximum $\dot{V}O_2$ stabilization intensity in cycle ergometer, once the results found supported this equivalency.

Methodological differences between our study and the study conducted by Hill and Smith[14] may be emphasized. In that study, the $\dot{V}O_2$ collections were performed each 15 seconds and the $\dot{V}O_{2peak}$ was considered as the highest average value of 30 seconds (two samples) during each load. The $t_{\dot{V}O2peak}$ was considered as the time elapsed from the beginning of the rectangular load until the middle of the 15-second interval in which the $\dot{V}O_{2peak}$ was reached. In the present study, we adopted a fixed $\dot{V}O_{2peak}$ value, measured in progressive effort test with tolerance given by the $CI_{95\%}$. In addition, the samples of exhaled gases for the $\dot{V}O_2$ calculation were collected each three ventilatory incursions, making the intervals between records of the physiological variable irregular. Thus, similar results were obtained in both investigations with regard to the equality of PCrit and PCrit'.

A limitation of this study was the absence of prolonged rectangular exercise sessions at intensity corresponding to PCrit, PCrit' and PET with the objective of corroborating the $\dot{V}O_2$ stabilization at levels below $\dot{V}O_{2max}$ and the perceived exertion in values below 20, which is the highest possible value in the 15-point Borg scale. It is possible that in the intensity associated to these physiological indicatives of aerobic capacity, the perceived exertion would not present steady state, what would not necessarily make the conclusion of this study unfeasible. One may speculate that the increase on the perceived exertion along the exercise out of severe domain (heavy and moderate) would be given by other factors such as the glycogen depletion and the increase on the body temperature rather than the CTAnaer utilization. Moreover, the electromyographic signal measurement during severe predictive trials and during rectangular sessions in the transition between heavy and severe domains could provide some hints on the causal relation between neuromuscular activation and perceived exertion. We intend to test these experimental conditions in further studies.

From the practical point of view, the PET seems to be an interesting alternative in the prediction of PCrit and maximum $\dot{V}O_2$ steady state. All these indicatives are associated to the aerobic capacity of individuals and could be employed in its evaluation, in the monitoring of training-induced alterations and also as parameter for the prescription of aerobic training. The advantage of using PET in relation to the technique proposed by Hill and Smith[14] to estimate PCrit' is its simplicity, where the use of any equipment is dispensable and for allowing the follow-up of the subjective effort performed at different loads, which composed an integrated response of the stress external conditions imposed by exercise. Theoretically, it seems that the PET validity implicates the addition of new elements to the critical power model traditionally investigated as a purely energetic model, also presenting an impact on the notion of effort domains transition[9]. The relations between the concept of error signal of Hughson *et al.*[25] in the induction of the $\dot{V}O_2$ increase, concomitantly reduced to the use of part of the CTAnaer also deserve attention in further studies.

CONCLUSIONS

The results of the present study corroborate original findings of Nakamura *et al.*[1] in water running, that PET may be an alternative measurement of PCrit, estimated in this study by means of cycle ergometer tests. Moreover, these variables were also equivalent to the indicative of maximum $\dot{V}O_2$ steady state or PCrit'. Thus, one concludes that PET is defined as an indirect technique for the determination of the transition between severe and heavy effort domains[9], where theoretically the physiological variables including $\dot{V}O_2$ and the psychological variables (perceived exertion) would present steady behavior, allowing the performance of prolonged exercises.

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