Comparison between direct and indirect protocols of aerobic fitness evaluation in physically active individuals

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ABSTRACT

The individual anaerobic threshold (IAT), individual glucose threshold (IGT), critical velocity (CV), and the velocity associated to $\dot{V}O_{2max}$ (Vmax) and to 3,000 m running performance (Vm3km) have been used for the aerobic evaluation and exercise prescription in runners. However, a comparison of these variables and their usefulness for physically active non-athlete individuals were not investigated yet. The objectives of this study were to compare and to verify the relationship between Vmax, Vm3km, CV, IAT and IGT in physically active non-athlete individuals. Eleven healthy and physically active individuals (20.7 ± 1.8 yr., 74.2 ± 14.5 kg, 48.9 ± 5.8 $mlO_2.kg.min^{-1}$), randomly accomplished to the following running tests on different days: 1) 3,000 m performance for Vm3km; 2) an all-out 500 m running track and 3) an incremental treadmill test for IAT, IGT, $\dot{V}O_{2max}$ and Vmax determination. The CV was determined by linear regression (distance-time relation) by using the 3,000 m and 500 m running tests. The running velocities corresponding to IAT, IGT, Vmax, Vm3km and CV were 184.8 ± 27.7; 182.8 ± 27.9; 211.1 ± 30; 213.4 ± 32.2 and 199.8 ± 30.4 $m.min^{-1}$, respectively. Despite the high correlation between the parameters studied, the CV overestimated the IAT and IGT ($P < 0.001$). However, no significant differences were verified between Vmax and Vm3km ($P > 0.05$). We concluded that the Vm3km can be used for Vmax estimation and that CV identification on track may be useful for aerobic evaluation as well as for delimiting the high to severe exercise intensity domains. However, the CV does not seem be a good estimation of anaerobic threshold for physically active individuals.

Key words: Individual anaerobic threshold. Individual glucose threshold. Critical velocity. Vmax. Performance.

INTRODUCTION

The aerobic evaluation is possible due to the determination of the maximum oxygen intake ($\dot{V}O_{2max}$) and the associated running velocity (Vmax)[1,2] as well as the anaerobic threshold identified based on the responses of blood lactate (lac) and blood glucose (gluc)[3-7].

The Vmax is an intensity in which the $\dot{V}O_{2max}$ may be reached and has been associated with the average velocity employed in 3,000 m running performance (Vm3km)[1,2]. It has been evidenced that the Vm3km presents high correlation with the velocity corresponding to the individual anaerobic threshold (IAT), being useful to predict the anaerobic threshold of track runners[6].

It has also been evidenced that the IAT protocol identifies the highest exercise intensity that can be maintained in lac[3] dynamic steady state and that this protocol suffers no influence from small methodological variations such as the number and duration of stages and the type of warm-up exercises previously performed[8].

Simões *et al.*[6] reported similarities between gluc and lac responses of runners during track incremental tests and proposed the identification of the individual glucose threshold (IGT), which intensity was not different from IAT.

$\dot{V}O_{2max}$, Vmax, IAT and IGT have been used in the aerobic assessment[1,6,7,9] and their identification depends on expensive equipments (treadmills, equipments for ventilatory analysis and lactate and glucose analyzers) as well as on the participation of skilful professionals and the use of invasive techniques for blood collections. As alternative, easy-to-apply and non-invasive protocols have been proposed with emphasis for the application of mathematical models that enable the identification of the critical velocity (CV) based on the distance-time relation in performance tests conducted in track running, swimming and cycling[9-15].

CV is a parameter of aerobic fitness that has shown to be sensible to the endurance training[16], with high correlation with the anaerobic threshold[15,17,18], being identified based on hyperbolic and linear models[10]. Most studies on the CV were conducted with athletes[9,11-14] and as far as we know, the literature lacks of studies that investigate the relation between CV and other parameters of aerobic fitness in non-athlete individuals. The CV has been compared with the anaerobic threshold identified both by the steady concentration of 4 $mmol.l^{-1}$ of lac[12] according to methodology described by Heck *et al.*[19] as well as from techniques that consider the individual behavior in relation to the lac[13] and ventilation[20] response and it has been demonstrated that the CV may overestimate the anaerobic threshold intensity[13,14,20].

Despite previous studies have related the performance of middle-distance runners with Vmax, CV and anaerobic threshold[9,10,20,21], the parameters CV, Vmax, Vm3km, IAT and IGT have not yet been compared for non-athlete physically active individuals.

OBJECTIVES

To compare intensities associated to IAT, IGT, Vmax, CV and Vm3km and to analyze the possibility of using indirect tests in the assessment and prescription of exercise intensities for non-athlete physically active individuals.

METHODS

Eleven healthy Physical Education students, who participated in physical activities at least twice a week with no competition purposes participated in this study (table 1). The procedures of this study were previously approved by the Ethics Committee in Researches involving human beings and all participants responded to an anamneses questionnaire and signed an consent term inform-

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ing about the procedures, risks and benefits resulting from their participation.

Before being submitted to physical tests, the volunteers participated of a four-week adaptation program composed of two weekly exercise sessions involving motor coordination, muscular stretching, running at sub maximal velocity and some trials of the tests to be applied in the methodology of the present study. The trials included 500 m and 3,000 m cadenced running in order to provide apprenticeship on the execution of tests to be applied for the determination of CV.

At the end of the adaptation period, specific tests were performed, which were preceded of 15 minutes of warm-up and muscular stretching exercises. Each participant were informed to hydrate himself adequately and to ingest meals at least three hours before tests, besides avoiding the performance of exercises during the 48 hours before his participation.

TABLE 1
Characteristics of the individuals studied

n = 11	Age (years)	Weight (kg)	$\dot{V}O_{2max}$ ($mlO_2.kg.min^{-1}$)
Average	20.7	74.2	48.9
± SD	1.8	14.5	5.8

Determination of Vm3km and CV

The Vm3km was obtained through 3,000 m running performed in the shortest time as possible. The CV was determined by means of linear model using the distance-time relation based on the performance in 3,000 m and 500 m running, which were measured in running track in different days. The linear regression straight line inclination defined the CV, as proposed by Hill[10] (figure 1).

Determination of IAT and IGT

According to methodology used by Simões *et al.*[6,7], the test was performed in treadmill (Johnson JET 7000, USA) at 1% inclination, initial velocity corresponding to 75% of the Vm3km and increments of 0.5 $km.h^{-1}$ each three minutes with 1 min of interval for the collection of 25 ml of capillary blood from the earlobe. The blood samples were transferred into Eppendorf tubes containing 50 ml of NaF 1% for gluc and lac dosages (YSI 2300 STAT plus – Ohio USA).

The heart rate (HR) was controlled during the entire test (Polar Sport Tester, Finland). When volunteers reached 95% of the theoretical maximal HR previously defined by the equation of Wilson & Tanaka[22] and/or when the exertion subjective perception indicated by volunteer reached 17 points in the scale proposed by Borg[23], the velocity was maintained and only the treadmill inclination was raised 1% each minute with no intervals up to voluntary exhaustion[7,24].

Blood samples were also collected each three minutes during 12 minutes of post-exercise recovery for the kinetic analysis of lac and IAT identification (Stegmann *et al.*)[3]. The IGT was identified as the velocity corresponding to the moment in which the gluc presented an increase during the test (figure 2).

Determination of $\dot{V}O_{2max}$ and Vmax

The $\dot{V}O_{2max}$ was determined in the same incremental test applied for the IAT and IGT identification. Ventilatory variables were measured during the 20 final seconds of each stage ($\dot{V}O_{2000}$ Aerosport-Medgraphics) and the $\dot{V}O_2$ obtained at the end of the test (moment of voluntary exhaustion) was considered as the $\dot{V}O_{2max}$.

The running velocity associated to $\dot{V}O_{2max}$ (Vmax) was determined through method proposed by Di Prampero[25] as follows:

$$Vmax = \dot{V}O_{2max} \cdot C^{-1} \qquad C = \dot{V}O_{2\ sub\ maximal} \cdot load_{sub\ maximal}^{-1}$$

where: $\dot{V}O_{2\ sub\ maximal}$: oxygen intake at sub maximal load. **Load** $_{sub\ maximal}$: velocity at stage prior to the beginning of treadmill inclination increase during incremental test. **C**: oxygen cost

Statistical analysis

Data are expressed as average and standard deviation. The analysis of variance ANOVA for repeated measures with *post hoc* Tukey-Kramer test were used in order to compare IAT, IGT, Vmax, VC and Vm3km velocities. The correlations between variables were determined with the application of the Pearson correlation test. The significance level adopted was of $p < 0.05$.

RESULTS

The determination of CV, IAT and IGT for all participants was similar to that presented in figures 1 and 2. The average results of velocities corresponding to IAT, IGT, CV, Vmax and Vm3km are presented in table 2.

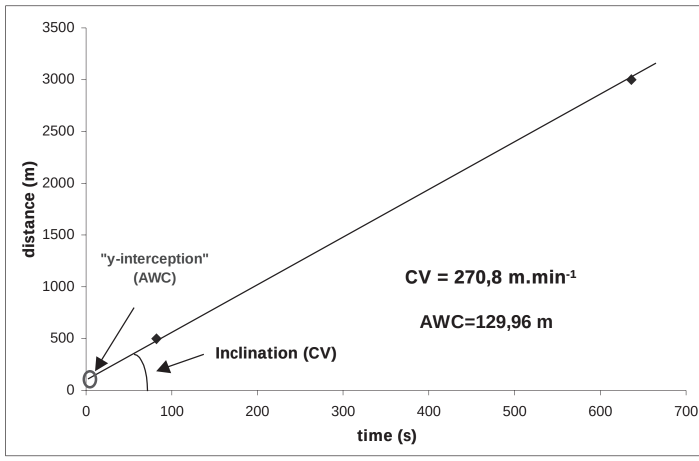

Fig. 1 *– Determination of CV for a given participant through linear model (distance – time relation) based on 3,000 m and 500 m tests. The regression straight line inclination defines the CV.*

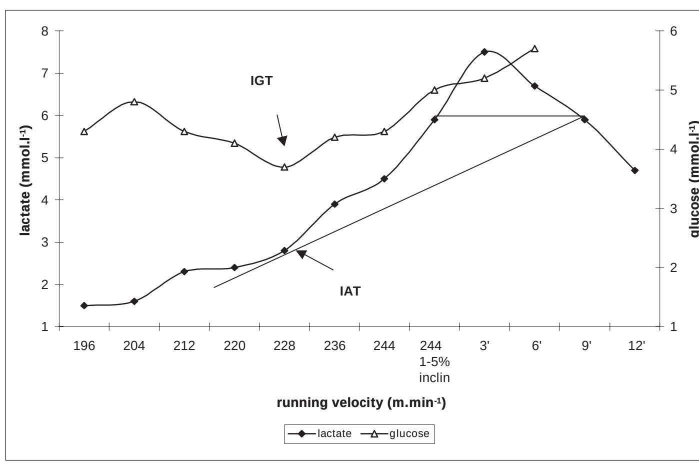

Fig. 2 *– Incremental test in treadmill for the identification of IAT, IGT, $\dot{V}O_{2max}$ and Vmax for a given individual (modified from Simões et al.[7]).*

The ANOVA showed no differences statistically significant between Vmax and Vm3km as well as between IAT and IGT (table 2) and all parameters presented high correlations between each other (table 3). CV, IAT and Vmax, despite highly correlated, were different from each other (P < 0.001), therefore reflecting different parameters.

TABLE 2
Results of velocities (m.min-1) corresponding to the parameters studied

	Vmax (m.min-1)	Vm3km (m.min-1)	CV (m.min-1)	IAT (m.min-1)	IGT (m.min-1)
Average	211.1	213.4	199.8♣	184.8♦	182.8♦
± SD	30	32.2	30.4	27.7	27.9

♦: $p < 0.001$ in relation to Vmax, Vm3km and CV.
♣: $p < 0.001$ in relation to all parameters.

TABLE 3
Correlation between the parameters studied

	CV	IAT	Vmax	IGT
Vm3km	r = 0.99*	r = 0.97*	r = 0.92*	r = 0.97*
CV	–	r = 0.97*	r = 0.94*	r = 0.98*
IAT	–	–	r = 0.96*	r = 0.99*
Vmax	–	–	–	r = 0.95*

* $p < 0.0001$

DISCUSSION

The high correlation observed between the variables studied suggests that, besides the use of direct tests (with measurements of lac, gluc and $\dot{V}O_2$), the aerobic fitness may also be assessed based on non-invasive indirect tests such as the CV and Vm3km determinations. In the present study, no differences between Vmax and Vm3km and between IAT and IGT were observed. On the other hand, the CV was lower than Vmax and Vm3km and overestimated the IAT and IGT in approximately 8.7%, suggesting that the CV should not be used as anaerobic threshold reference.

The similarity observed between results of Vmax and Vm3km is in agreement with results from other studies performed with runners[1,26,28]. However, the contribution of the present study is that these results could be also observed in non-athlete physically active individuals, suggesting that the use of running performance results such as the Vm3km is a low-cost practical method for Physical Education professionals who want to assess their students/clients and to prescribe individualized training programs.

The Vmax identification is very important and seems to be effective in the evaluation and prescription of training intensities for long-distance runners[2]. The effects of training on the Vmax/Vm3km in non-athlete individuals needs further investigations. However, Smith *et al.*[2] observed significant evolution on $\dot{V}O_{2max}$ and on the performance in middle-distance running (improvements on the Vm3km) in runners after training programs performed at the Vmax intensity.

In relation to the anaerobic threshold determination based on the lac and gluc responses, our results indicate that the IAT and IGT reflect the same parameter (table 2). A possible explanation for the increase on gluc after reaching the anaerobic threshold during incremental tests (figure 2) is that the adrenergic activity and the release of hormones associated to hyperglycemia – such as adrenaline, glucagon and cortisol – are increased at intensities above the anaerobic threshold[29], resulting in increased gluc and enabling the IGT identification[6,7,29]. The identification of a glycemic threshold and the possibility of using this parameter in order to delimit intensity domains with prevalence of gluc uptake and production is relevant and needs to be better investigated. Studies on the IGT identification and its application in diabetic individuals have been performed by our research group and we have observed that intensities below IGT seem to be adequate to promote a better control of the blood glucose content in individuals presenting hyperglycemia[30].

In relation to the CV, even with the use of only two predictive series for its identification (distances of 500 m and 3,000 m), the results obtained are in agreement with other studies, suggesting that the CV is slightly higher than the anaerobic threshold and lower than the Vmax[11,14,15,20,31]. Thus, despite the validity of CV as an aerobic fitness parameter has been investigated and discussed by many authors, our results emphasize that the IAT and CV identified different intensities and that the CV cannot be used as anaerobic threshold reference.

On the other hand, the CV presented high correlation with the other parameters, indicating that its determination in running track may be a low-cost, accessible and practical alternative to assess young and physically active individuals. Moreover, its identification has been proposed as a low-cost method that, besides assessing the aerobic fitness and predicting the performance in endurance events[20], allows delimiting high to severe exercise intensity domains[32]. Gaesser and Poole[33] defined three exercise intensity domains based on their different metabolic profiles as follows: a) moderate, which corresponds to intensities lower than or equal to the "anaerobic threshold"; b) high intensity, which is greater than the anaerobic threshold but does not exceed the critical power or critical velocity; and c) the severe domain, which corresponds to intensities above the critical power or critical velocity.

At intensities corresponding to the "critical power" or "critical velocity", the $\dot{V}O_2$ reaches a steady state. On the other hand, at intensities above the critical power (ex. 8-10% above the critical power), the $\dot{V}O_2$ may reach its maximum value ($\dot{V}O_{2max}$)[34]. Hill *et al.*[32], in tests performed in cycle ergometer, observed that the upper limit of the severe intensity is an intensity above which the exhaustion would occur before the $\dot{V}O_{2max}$ was reached and received the denomination of extreme domain. These authors identified that the upper limit of the severe domain and the lower limit of the extreme domain occurred at approximately 135% of the critical power, while the lower limit of the severe domain was simply above the critical power. Based on the findings of the present study, the CV identification allows assessing the aerobic fitness and identifying the "high" and "severe" intensities domains, thus providing subsides for the selection of exercise intensities within intensity domains of interest.

The Vmax and Vm3km corresponded to approximately 107% of the CV, in other words, intensities within the severe domain that would allow reaching $\dot{V}O_{2max}$ during exercises performed at this intensity. For the high intensity domain, intensities below CV (and above IAT) could be selected[2] and our results indicated that the CV and the anaerobic threshold velocities (IAT and IGT) corresponded to 94 and 87% of the Vm3km (or Vmax), respectively, yet suggesting that intensities relative to Vm3km may be used to estimate and/or to prescribe exercises within the intensity domains of interest (moderate, high or severe).

CONCLUSION

We conclude that the Vm3km and Vmax, as well as IAT and IGT reflect the same parameter, while the CV overestimates IAT and IGT and should not be used as anaerobic threshold reference. Finally, we suggest that the CV and Vmax (or Vm3km) may be useful in the characterization of the domain of interest in which the exercise is performed, thus allowing its application in the training prescription.

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