Original article (short paper)

Critical velocity estimates lactate minimum velocity in youth runners

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Abstract—In order to investigate the validity of critical velocity (CV) as a noninvasive method to estimate the lactate minimum velocity (LMV), 25 youth runners underwent the following tests: 1) 3,000m running; 2) 1,600m running; 3) LMV test. The intensity of lactate minimum was defined as the velocity corresponding to the lowest blood lactate concentration during the LMV test. The CV was determined using the linear model, defined by the inclination of the regression line between distance and duration in the running tests of 1,600 and 3,000m. There was no significant difference (p=0.3055) between LMV and CV. In addition, both protocols presented a good agreement based on the small difference between means and the narrow levels of agreement, as well as a standard error of estimation classified as ideal. In conclusion, CV, as identified in this study, may be an alternative for noninvasive identification of LMV.

Keywords: athletes, running, anaerobic threshold, performance

Resumo—"Velocidade crítica estima velocidade de lactato mínimo em corredores adolescentes." Com o objetivo de investigar a validade da velocidade crítica (VC) como método não invasivo de estimar a velocidade de lactato mínimo (VLM), 25 corredores adolescentes foram submetidos aos seguintes testes de corrida: 1) 3000m; 2) 1600m; 3) teste de VLM. A intensidade de lactato mínimo foi definida pela velocidade correspondente à menor concentração de lactato sanguíneo durante o teste de VLM. A VC foi determinada utilizando-se o modelo linear, sendo definida pela inclinação da reta de regressão distância-tempo nos testes de corrida de 1600 e 3000m. Não houve diferença significativa (p=0,3055) entre VLM e VC. Além disso, ambos os protocolos apresentaram uma boa concordância, baseado na pequena diferença entre as médias e nos estreitos limites de concordância, bem como um erro padrão de estimativa classificada como ideal. Em conclusão, a VC, como identificada no presente estudo, pode ser uma alternativa para identificação não invasiva da VLM.

Palavras-chave: atletas, corrida, limiar anaeróbio, desempenho

Resumen—"Velocidad crítica estima velocidad de lactato mínimo en corredores jóvenes." Con el objetivo de investigar la validez de la velocidad crítica (VC) como un método no invasivo de estimar la velocidad de lactato mínimo (VLM), 25 corredores jóvenes realizaron las siguientes pruebas de carrera: 1) 3.000m; 2) 1.600m; 3) prueba de VLM. La intensidad de lactato mínimo fue definida como la velocidad correspondiente a la menor concentración de lactato sanguíneo durante la prueba de VLM. La VC fue determinada utilizando el modelo lineal, definido por la inclinación de la recta de regresión distancia-tiempo en las pruebas de carrera de 1.600 y 3.000m. No hubo diferencia significativa (p=0,3055) entre VLM y VC. Además, ambos protocolos tuvieron una buena concordancia, basado en la pequeña diferencia entre las medias y los estrechos límites de concordancia, así como un error padrón

de la estimación clasificado como ideal. En conclusión, la VC, como identificado en este estudio, puede ser una alternativa no invasiva para la identificación de VLM.

Palabras claves: atletas, carrera, umbral anaeróbico, rendimiento

Introduction

Blood lactate responses ([lac]) during exertion tests have been the focus of several studies (review of Faude, Kindermann, & Meyer, 2009), being the maximal lactate steady state (MLSS) considered the gold standard of aerobic capacity, since it represents the highest intensity of exercise in which [lac] remains in equilibrium during an exercise with constant workload (Beneke, 2003). The MLSS delimits an intensity of exercise with a stable physiological ratio between lactate and pyruvate, oxygen pressure, carbonic acid (HCO_3^-), excessive basicity, oxygen uptake (O_2), respiratory exchange ratio (RER), ventilation (VE), and the ventilatory equivalent of oxygen (VE/O_2) and carbon dioxide (VE/CO_2) (Baron *et al*., 2003). Thus, the MLSS has been considered the optimal intensity for exercise prescription when training aims benefits associated with the improvement of aerobic capacity (Baron *et al*., 2008).

However, despite its accuracy on aerobic fitness evaluation, the MLSS protocol is time consuming, and depends upon evaluators with the ability to perform blood sampling and lactate analysis using expensive equipment. This, in turn, reduce the accessibility to such protocol (Franken, Zacca, & Castro, 2011), therefore derailing its application in large samples (Hiyane, Simões, & Campbell, 2006). In this scenario, the lactate minimum test (LM) proposed by Tegtbur, Busse and Braumann (1993), which is characterized by the equilibrium point between the production and removal of blood lactate during an incremental test after performing a high intensity exercise, appears as an alternative when it regards MLSS, since several studies show that the lactate minimum velocity (LMV) agrees with the intensity of MLSS, with the convenience of being performed in a single test session (Pardono *et al*., 2009; Puga, Kokubun, Simões, Nakamura, & Campbell, 2012; Sotero *et al*., 2007; Sotero *et al*., 2009).

Aiming to understand the validity and explore the potentiality and application of the LM, studies have been performed using different protocols for hyperlactatemia induction as well as distinct recovery regimens (Denadai & Higino, 2004; Higino & Denadai, 2002; Pardono, Simões, & Campbell, 2005; Santhiago, Silva, Guglielmo, & Higino, 2008; Smith, Balmer, Coleman, Bird, & Davison, 2002; Sotero *et al*., 2011). In addition, different populations including animals (Simões, Denadai, Baldissera, Campbell, & Hill, 2005; Simões, Campbell, Baldissera, Denadai, & Kokubun, 1998; Tegtbur *et al*., 1993; Tegtbur, Machold, Meyer, Storp, & Busse, 2001; Voltarelli, Gobatto, & de Mello, 2002; Zagatto *et al*., 2004), different ergometers (Carter, Jones, & Doust, 1999; MacIntosh, Esau, & Svedahl, 2002; Zagatto *et al*., 2004), environmental conditions (Pardono *et al*., 2009; Sotero *et al*., 2009; Tegtbur *et al*., 1993), and the use of mathematical equations (Simões *et al*., 2009) have also been used regarding this test. Furthermore, evidences have shown that the LMV protocol has sensitivity for the effects of aerobic training (Campos *et al*., 2014; Silva, Bonette, Santhiago, & Gobatto, 2007).

However, the use of LMV protocol also characterizes itself as an invasive and expensive procedure, differing from MLSS only when it comes to numbers of sessions in which the volunteers are submitted. One alternative would be the use of indirect methods to identify velocities similar to the LMV and MLSS, such as the critical velocity (CV), which has been used in several studies (review of Leclair, Mucci, Mcgawley, & Berthoin, 2008). Theoretically, CV has been suggested as an intensity of physical exercise that can be sustained for a long period of time without exhaustion (Monod & Scherrer, 1965), being characterized as a noninvasive low cost method that can be easily applied to evaluate aerobic capacity and to identify the intensity for exercise prescription (Leclair *et al*., 2008).

On the other hand, no study has been found regarding this subject (CV *vs.* LMV) in youth runners, while other studies have obtained positive results with adult runners (Simões *et al*., 2005) and athletes from other modalities (Altimari, Altimari, Gulak, & Chacon-Mikahil, 2007; Hiyane *et al*., 2006). Therefore, it is of interest better understand and compare both methods in adolescents, since this population tends to present lower blood lactate concentrations, due to lower enzymes concentration of glycolytic and higher of aerobic pathways (Dotan *et al*., 2012). In this sense and due to the need of utilizing non invasive and low cost methods with the capability of evaluate aerobic capacity and to identify intensity for exercise prescription in running, the aim of the present study was to compare the CV and LMV in youth runners.

Methods

The present study was approved by the ethics committee of the Catholic University of Brasília (UCB – nº 019/2004). All participants were instructed not to perform exercise and not to drink caffeine beverages during the 24 hours that preceded the experimental procedures. After being informed of the risks and benefits of the study and having signed an informed consent letter, 25 medium and long distance youth runners (table 1) from the Joaquin Cruz Institute were submitted to three experimental sessions performed in a 400m athletics track, with a minimum of 48 hours between them. In the period of collection, all athletes were national sporting level, and were in pre competition period with a training volume between 40-50 miles per week.

3,000m running performance test

The participants performed a 3,000m running test in a 400m athletics track in order to obtain the mean velocity (mV 3,000m) of the test. The volunteers were guided to run the distance as fast as possible. The result obtained was used to calculate the intensity of the stages in the lactate minimum incremental tests and the linear regression equation to obtain the CV.

1,600m running performance test

The participants performed a 1,600m running test in order to obtain the mean velocity (mV 1,600m) of the test. The volunteers were guided to run the distance as fast as possible. The result obtained was used in the linear regression equation to obtain the CV.

Incremental test for determination of lactate minimum velocity

Determination of LMV was performed according to the incremental test proposed by Simões *et al*. (1998), in which the participants ran 500m at maximum speed in order to induce hyperlactatemia, followed by 10min of recovery and 6 incremental sets of 800m at the intensities of 83, 86, 89, 92, 95 and 98% of the mV 3,000m. The velocities during the incremental tests were controlled by a sonoric stimulus at each 100m. Pauses with 1min of duration between each set were executed in order to collect 25µl of blood from the ear lobe using procedure gloves, disposable lancets and calibrated and heparinized glass capillars. Afterwards, the samples were stored in Eppendorf microtubes containing 50µl of NaF at 1%. Blood lactate responses were analyzed through the electroenzymatic method (Yellow Springs 2700, STAT, OH, EUA). The procedures used to identify the LMV are shown in Figure 1. The running velocity corresponding to the lowest concentration of [lac] during the incremental test was determined by visual inspection (Tegtbur *et al*., 1993).

Calculating the critical velocity

The time-distance linear model to determine CV was used as proposed by Kranenburg and Smith (1996) for field tests with trained runners. This model does not differ from other models in running (Simões *et al*., 2005). Only two distances (coordinates) were adopted in order to obtain CV, as previously cited (De Lucas, Dittrich, Junior, de Souza, & Guglielmo, 2012; Pacheco, Silva, Baldissera, Campbell, Liberti, 2006; Penteado *et al*., 2014; Silva, Pacheco, Campbell, Baldissera, & Simões, 2005; Simões *et al*., 2005). The distances were chosen with at least a 5min interval between durations (Housh, Housh, & Bauge, 1990) and allowing a total trial time between 3 and 15 min, as recommended (Greco, 2000; Kranenburg & Smith, 1996).

After adjust the optimal distance to reach the previously described recommendations (Greco, 2000; Housh *et al*., 1990; Kranenburg & Smith, 1996), CV was determined through the inclination of the regression line between the 1,600m and 3,000m performance tests results and their respective durations. In this equation, the inclination of the regression line indicates the intensity of velocity correspondent to the CV, where the same can be obtained by the following equation CV ($m \cdot s^{-1}$) = (2^{nd} distance – 1^{st} distance) / (2^{nd} duration – 1^{st} duration). Figure 2 shows an example where the inclination of the regression line represents the intensity corresponding to the CV.

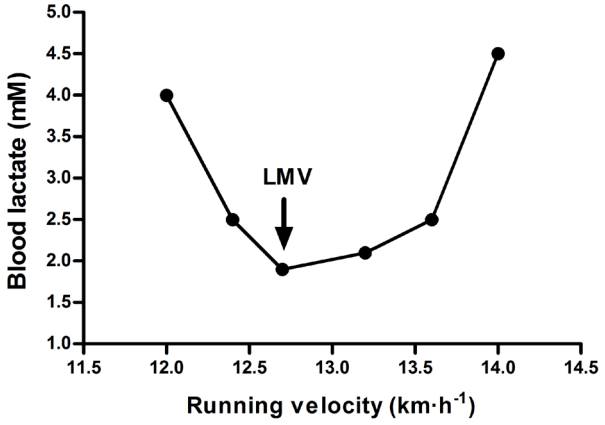

Figure 1. Example of lactate minimum velocity (LMV) determination in a single participant#1 (LMV= 12.7 $km \cdot h^{-1}$).

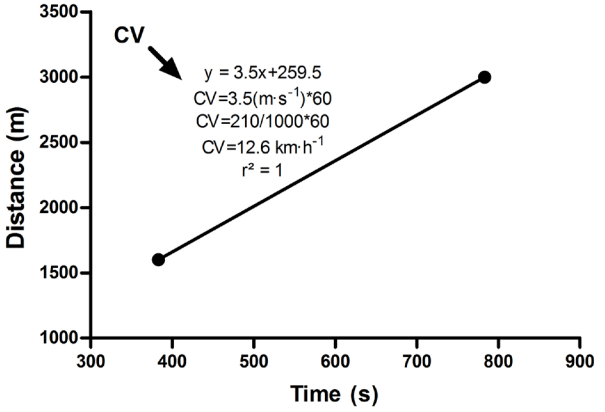

Figure 2. Example of critical velocity (CV) determination using the distance-time linear model for the participant#1 (CV= 12.6 $km \cdot h^{-1}$).

Statistical analysis

After verification of data normality through skewness and kurtosis, a descriptive analysis (mean ± standard deviation) was performed. In order to compare CV and LMV, a paired Student's *t*-test was applied. In addition, effect size was tested using Cohen's *d* test. Linear regression was adjusted by gender and performed to verify the degree of association between the protocols (CV and LMV), as well as the variance analysis to confirm the hypothesis of regression. Bland and Altman's technique (Bland & Altman, 1999) was used to attest the level of agreement between the different tests. Lastly, the standard error of estimate (SEE) between the protocols was calculated. The level of significance adopted was 5% ($p < .05$) and all analyses were performed using the Statistical Package for the Social Sciences (SPSS) 18.0.

Results

The results from the present study show no significant difference ($p = .305$) between the LMV and CV. In addition, both protocols presented a good agreement based on the small difference between means and the narrow levels of agreement [0.2 (1.9) $km \cdot h^{-1}$]

(Figure 3). Furthermore, the difference between means presented a small effect size (*d*= .123) and a SEE below 2.0% (Table 2).

Linear regression, adjusted by gender, between the CV and LMV presented a significant association (r^2= 0.397, *p*= .004), besides of an *F* value of 7.245, significantly for *p*= .004 (Figure 4).

Table 1. Main characteristics of the sample (n=25). Data expressed in mean ± standard deviation.

Variables	Mean ± standard deviation
Age (years)	14.7 ± 1.2
Gender (boys/girls)	18/7
Mass (kg)	48.9 ± 10.4
Height (cm)	160.0 ± 1.0
BMI (kg·m^{-2})	18.6 ± 2.0
mV 3,000m (km·h^{-1})	14.3 ± 1.3
mV 1,600m (km·h^{-1})	15.8 ± 1.0

BMI – body mass index; mV 3000m – mean velocity at the 3,000m running test; mV 1600m – mean velocity at the 1,600m running test.

Table 2. Paired Student's *t*-test (*p*), effect size (*d*) and standard error of estimate values for critical velocity (CV) and lactate minimum velocity (LMV) in youth runners (*n*=25)

CV (km·h^{-1})	LMV (km·h^{-1})	*p*-value	*d*	SEE (%)
13.5±1.9	13.3±1.3	.305	.123	0.94623

CV – critical velocity; LMV – lactate minimum velocity; *d* – effect size; SEE – standard error of estimate.

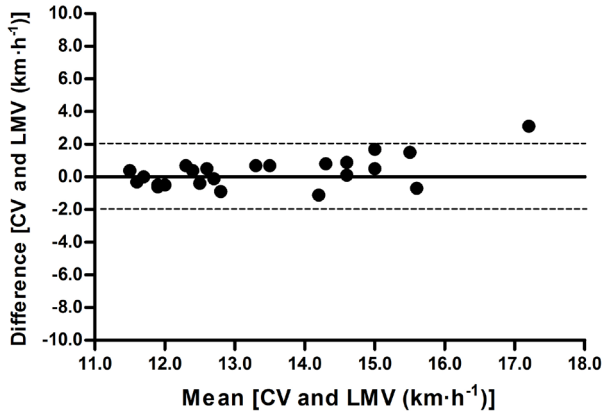

Figure 3. Bland and Altman analysis between critical velocity (CV) and lactate minimum velocity (LMV).

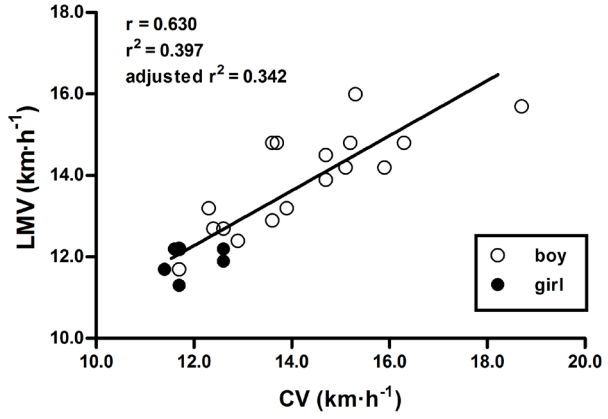

Figure 4. Linear regression adjusted by gender between critical velocity (CV) and lactate minimum velocity (LMV).

Discussion

The main finding of the present study was that CV seemed to estimate LMV in youth runners, presenting an association even when adjusted by gender, a good level of agreement, low effect size and a standard error of estimate below 2% between values. This indicates that CV can be an easily applied and is low cost alternative to evaluate male and female youth runners.

The findings of the present study agree with the ones in Hiyane's *et al*. (2006) in trained cyclists. Likewise, Altimari *et al*. (2007) found a positive association between the studied methods in adolescent swimmers. However, other studies have shown that CV overestimated LMV in trained canoeists (Nakamura *et al*., 2006) and adult runners (Simões *et al*., 2005). Simões *et al*. (2005) showed that CV overestimated LMV in adult runners. However, they reported a significant positive association between the methods and concluded that CV is a valid method to predict and evaluate performance. One reason that could explain this overestimation is the use of inappropriate test distances, which are crucial to determine CV (Franken *et al*., 2011).

The mean durations of the tests performed in the present study were 6.4min (1,600m) and 13.1min (3,000m), agreeing with the recommendations (Greco, 2000; Kranenburg & Smith, 1996). However, in order to efficiently perform the tests, it is important to know how trained the volunteers are and/or perform pilot studies, since short duration tests (less than 3min) can overestimate critical power (CP) or CV (Bishop, Jenkins, & Howard, 1998). In addition, in long duration tests (more than 20min) other factors contribute to exhaustion, such as thermoregulation, substrate depletion and motivation (Greco, 2000). Finally, the present study followed Housh's *et al*. (1990) recommendations, in which the distances chosen should respect a 5min interval.

In the present study only two coordinates to calculate CV were used, agreeing with previous studies (de Lucas *et al*., 2012; Pacheco *et al*., 2006; Penteado *et al*., 2014; Silva *et al*., 2005; Simões *et al*., 2005). Several studies have shown that two coordinates are enough to determine CV in adult trained runners (de Lucas *et al*., 2012; Simões *et al*., 2005), moderately trained adults (Smith, Kendall, Fukuda, Cramer, & Stout, 2011), physically active adults (Pacheco *et al*., 2006; Silva *et al*., 2005), adult cyclists (Hiyane *et al*., 2006) and youth swimmers (Altimari *et al*., 2007). Housh *et al*. (1990), for instance, submitted 12 young adults to four loads until exhaustion and CP was determined with two, three and four coordinates. They reported that CP determined by two coordinates was strongly associated with the values assessed by four coordinates (*r*= .80 - .99).

The identification of CV, as performed in the present study, allows the evaluation of aerobic capacity and identify the intensity for exercise prescription (Leclair *et al*., 2008). Furthermore, through CV it is possible to perform an evaluation in the competition venue or during training sessions (Kranenburg & Smith, 1996) without the need of expensive lab equipments. Regarding intensity, Toubekis and Tokmakidis (2013) suggest that running at CV displays characteristics a "very heavy" intensity, where VO_2 is close to maximum (VO_2max) and [lac] are very high. Billat, Binsse, Petit, & Koralsztein (1998) showed that

long distance runners with a CV corresponding to 86% of the VO_2max velocity (vVO_2max) were capable of exercising at an intensity of 90% of vVO_2max without achieving VO_2max and without cardiovascular drift, which is frequently observed in high intensity aerobic exercise. Similar findings were reported by Bull, Housh, Johnson, & Rana (2008).

In this scenario, de Lucas *et al*. (2013) reported that CP is the physiological index that estimates the limits between "heavy" and "severe" exercises in trained subjects. These authors evaluated the physiological responses and time to exhaustion in acute sessions until exhaustion at CP and 5% above CP, and showed that VO_2, VE, and [lac] obtained at the end of the 5% above CP exhaustion trial were not significantly different from the maximal variables. The physiological end values during the CP test were significantly lower than when compared to the incremental test, and time to exhaustion at CP was significantly higher than 5% above.

Curiously, it seems that exercise prescription using intermittent running protocols produce a better physiological balance and higher training volume when compared to continuous running protocols. Penteado *et al*. (2014) compared level of tolerance and physiological responses in running tests at CV until exhaustion between intermittent and continuous protocols and found that heart rate, perceived exertion and [lac] at the end of both exhaustion tests were not significantly different when compared with incremental treadmill test values. However, time to exhaustion was twice longer in the intermittent test when compared to continuous, and only the continuous session showed an increase 9.0±0.8 $mmol \cdot l^{-1}$ of [lac] at the end of exercise.

It is worth highlighting that the present study has some limitations. One of them was not comparing CV with the intensity of MLSS, which is considered the gold standard in aerobic capacity evaluation from [lac] responses (Beneke, 2003). However, several studies have demonstrated that there is no difference between MLSS and LMV (MacIntosh, Esau, & Svedahl, 2002; Pardono *et al*., 2008, 2009; Puga *et al*., 2012; Sotero *et al*., 2007, 2009). Another limitation was not assessing the participant's maturational state. In this matter, Frainer, Oliveira and Pazin (2006) verified no associations between sexual maturation, age and growth indexes with performance of running.

Conclusion

The combination of the predictive sets performed (1,600 and 3,000m), in order to obtain the CV proposed by the present study, presented values that did not differ from the ones obtained through LMV. Therefore, the test proposed in the present study is valid and CV did in fact estimate LMV in youth runners. This finding is important since CV is a low cost and non-invasive method of evaluating aerobic capacity and to identify the intensity for exercise prescription.

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