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Relationship between direct and indirect methods for determination of anaerobic running speed

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ABSTRACT:

The present study was to compare and correlate two methods for determination of AnT, through the behavior of blood lactate and an indirect test as critical velocity. A progressive testing of 6 x 1000 m in running track was performed in order to determine the AnTV and three tests with the distances of 1500 m, 3000 m, and 5000 m were performed in order to determine the VCrit. For the determination of AnTV, the behavior of blood lactate concentrations was used through two identification methods, IAT and DMAX. Bland-Altman's visual analysis was used to verify agreement and Pearson's test was used to identify the correlation. It was possible to identify positive correlations between the invasive and non-invasive methods used in the study, and the same was identified in the Bland-Altman's visual analysis. The study found that the anaerobic threshold velocities in the methods that used blood lactate with the indirect methods (Vcrit) are concordant among them, so the presented methods are safe for the training prescription considering the running speed in the anaerobic threshold (AnT) in runners moderately trained.

KEY WORDS Thresholds; Velocity's Control; Load Control; Field Test; Fatigue

INTRODUCTION

The aerobic component of the energy system becomes a key element for good performance in long-distance races, such as marathons [1] . Due to an increasing number of street racing and long-distance race practitioners, the exercise physiology applied to sport training has been seeking ways to better control the training, based on periodic evaluations that can subsequently

improve the capacity and the aerobic power in the practitioners of this sport modality through a substantiate prescription [2],[3].

One of the points of great interest in the prescription and control of training are the thresholds of physiological transition due to its close relationship with performance in long-distance races [4],[5][6]. Physiological transition thresholds are pedagogically divided in two: Aerobic threshold or first threshold and anaerobic threshold (AnT) or second threshold [2],[4][7]. AnT has attracted increased research interest in recent times, mainly by providing valuable information on the physiological active systems during exercise, thus supporting its applicability to the prescription and monitoring of the training progression for diverse populations, such as healthy individuals and high performance athletes [6]. Based on this premise, AnT have been widely used to verify the changes caused by a training season [6],[7].

In order to determine AnT, blood lactate concentrations [Lac] appear as a reliable measure, being denominated as lactate threshold (LT) and determined in the maximum exercise intensity where there is a balance between lactate production/removal rates in the blood. There are several methods for identifying AnT through blood lactate, such as the maximal lactate steady state (MLSS) [8], the fixed blood lactate concentration (2 or 4 mmol/L^{-1}) [9], [10], the individual anaerobic threshold (IAT) [11], and the DMAX [12]. However, the application and identification of AT through blood lactate requires high cost equipment, which minimizes the use of a large number of subjects in the research [13]. Based on this premise, the researchers began to seek indirect tests for AT evaluation, and one of the used methodologies is the AnT velocity test (AnTV), and the critical velocity (Vcrit), which corresponds to a boundary intensity of effort that can Be maintained with a steady state of VO_{2MAX} and lactate [14],[15],[16]. Vcrit is a non-invasive, easy to apply and low cost method suitable for application to a large number of people and must therefore be incorporated into the physical assessment protocols of amateur and professional race practitioners [17].

As already reported, there are sufficient basis for identifying AnTV through blood lactate methods and indirect methods, such as Vcrit [18]. However, the literature still reports gaps in verifying the agreement of different methods of the AnT identification and if these show relationships with the Vcrit, mainly when both methods are performed in field tests. Thus, the aim of the present study was to compare and correlate two methods for determination of AnT, through the behavior of blood lactate and an indirect test as critical velocity.

METHODS

Samples

Variables	
n	17
Age (Years)	34.46 ± 10.68
Height (m)	1.68 ± 0.36
Height (m)	68.28 ± 6.78
Body Fat (%)	12.27% ± 4.97
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In total, 17 moderately trained volunteer runners participated in the study, all signed the free and informed consent and the project was approved by Ethics Committee under the protocol number 53675416.3.0000.5148. Table I shows the sampling characteristics.

Table I. Anthropometric Characteristics of the Sample.

Procedures

Anthropometric evaluation

An anthropometric evaluation was performed for the sampling characterization, in which a scale with stadiometer (110 FF, Welmy®, Santa Bárbara d'Oeste, Brazil) was used. In order to perform bioimpedance, participants were instructed to abstain from alcoholic and/or caffeinated beverages as well as to practice vigorous physical activity for a period of at least 24 h before the evaluation. The fat percentage estimate was obtained by means of a 4-terminal sensing device (Quantum BIA-II, RJL Systems®, Clinton Township, USA), and electrodes (Bio Tetronic, Sanny®, São Bernardo do Campo, Brazil) were used for collection. In order to calculate the fat percentage, the resistance and reactance data obtained by the device were transferred to the *Body Composition* 2.1 software (Quantum BIA-II, RJL Systems®, Clinton Township, USA) and together with the height, body mass and wrist circumference data, it was possible to estimate the fat percentage of the participants.

Progressive testing in track (PTT)

Warm-up before starting the progressive testing in track (PTT) consisted of 5 min of running at 40% of the best time of 1000 m and a rest of 2 min and then another 5 min of running at 50% of the best time of 1000 m. At the end of the warm-up, a 2-min interval was observed for PTT beginning, which consisted of: 6 series of 1000 m with 2 min recovery. The first series started with an intensity of 75% of the best time of the season and in the successive series were performed increases of 5% in relation to the best time, and the last series was corresponded the speed the best mark of the season in the 1000 m [19].

Measurement of blood lactate

Initially, 1 min after completion of each stage of the run, the responsible evaluator, after asepsis using lancets (Accu-Chek Safe-T-Pro Uno, Roche®, Hawthorne, USA) and disposable gloves (Cremer®, Blumenau, Brazil), collected a blood sample by puncture in the earlobe. The first drop of blood was then discarded, and 25μL of capillary blood was collected shortly thereafter. Reagent strips (Accusport BM - lactate, Roche®, Hawthorne, USA) were used for collection. The previously validated and reliable portable lactate analyzer (Accusport, Boehringer Mannheim - Roche®, Hawthorne, USA) was used [20]. Before the tests, the lactate analyzer was calibrated with different standard solutions of known lactate concentrations (2, 4, 8, and 10 $mmol.l^{-1}$) according to the manufacturer's recommendations.

Determination of the lactate threshold

IAT: In order to identify the individual anaerobic threshold (LL_{IAT}), the used visual method whose employed criterion indicates the threshold for the second increase in the [Lac] value of at least 0.5 mmol/l from the previous value, where the value for the second increase was greater than or equal to the first increase [11]. This simple method makes it possible to identify the individual anaerobic threshold, identifying the values for speed ($AnTV_{IAT}$).

DMAX: The lactate threshold through the mathematical model Dmax (LL_{DMAX}) was determined by means of individual graphs, with [Lac] being plotted as a function of the exercise intensities. Subsequently, a third-degree polynomial adjustment was performed through a linear regression using the two extremes of the curve. The LL_{DMAX} was defined as the point of greatest distance obtained perpendicularly from the line originated by the linear regression and the curve originating from the polynomial equation. From that point, the $AnTV_{DMAX}$ [21], [12] was determined.

Critical velocity (VCrit): Three tests were performed on a running track of 400 m of coal: one test of 1500 m, one of 3000 m and one of 5000 m, respecting a 24 h interval among them. In all tests, subjects should travel these distances in the lowest possible time. The sample was randomized to perform the tests. Vcrit was determined through the relation of two distances, being:
A) $VCrit_a$ - 1500 and 5000 m;
B) $Vcrti_b$: 3000 and 5000 m.
The equation [22] was used to determine the Vcrit.

$$\textbf{Vcrit} = (2^{nd}\ \text{distance} - 1^{st}\ \text{distance}) / (2^{nd}\ \text{time} - 1^{st}\ \text{time}).$$

Statistics: To verify the normality and the homogeneity of the variances, Shapiro-Wilk and Levene tests were adopted. After the assumptions of normality and homogeneity of variances, the T test for paired samples was used to compare the $AnTV_{IAT}$, $AnTV_{DMAX,}$ $Vcrit_a$ and $Vcrit_b$ methods. In order to verify the correlation among the studied methods, the Pearson correlation coefficient was performed for $AnTV_{IAT}$, $AnTV_{DMAX,}$ $Vcrit_a$ and $Vcrit_b$. The interpretation of Pearson correlation coefficient was assessed according to the following criteria: 0 - 0.30 negligible; 0.30 - 0.50 weak; 0.50 - 0.70 moderate; 0.70 - 0.90 strong and 0.90 - 1.00 very strong [23] . To evaluate the agreement among methods in the respective study variables, the visual analysis of the Bland-Altman plot [24] was used. Effect size (ES) was calculated according to Cohen's d (0.20 weak; 0.50 moderate; 0.80 strong). As statistical evidence, it was adopted the significance level (α) of 5%, being the statistical analysis performed with *SPSS* software (20.0, IBM, Armonk, USA).

STATISTICAL RESULTS

Figure 1 (a, b and c) shows the agreement among the IAT method with other methods (DMAX, $Vcrit_a$ and $Vcrit_b$), in which agreement among methods was verified by Bland-Altmann analysis. In Figure 2 (a and b), we identified agreement through the Bland-Altmann analysis of the DMAX method with the other used procedures ($Vcrit_a$ and $Vcrit_b$). Although in Figure 3, we identify correlation between $Vcrit_a$ and $Vcrit_b$. Table II shows the correlations among the methodologies used to identify the AnTV. While $AnTV_{IAT}$ x $AnTV_{DMAX}$ and $Vcrit_a$ x $Vcrit_b$ showed a strong correlation, $AnTV_{IAT}$ and $Vcrit_b$, $AnTV_{DMÁX}$ and $Vcrit_a$, and $AnTV_{DMÁX}$ and $Vcrit_b$ showed a moderate correlation, and the correlation between $AnTV_{IAT}$ and $Vcrit_a$ was weak. In Table III, we show the AnTVs in four used methodologies and we highlight significant differences between $AnTV_{IAT}$ x $AnTV_{DMAX}$ and between $AnTV_{DMAX}$ and $Vcrit_a$. In comparisons to verify the effect size, we identified that all methodologies ATV_{IAT} x $AnTV_{DMAX}$, $AnTV_{IAT}$ x $Vcrit_a$, $AnTV_{IAT}$ x $Vcrit_b$, $AnTV_{DMAX}$ x $Vcrit_a$, $AnTV_{DMAX}$ x $Vcrit_b$, and $Vcrit_a$ x $Vcrit_b$ one has a large effect size.

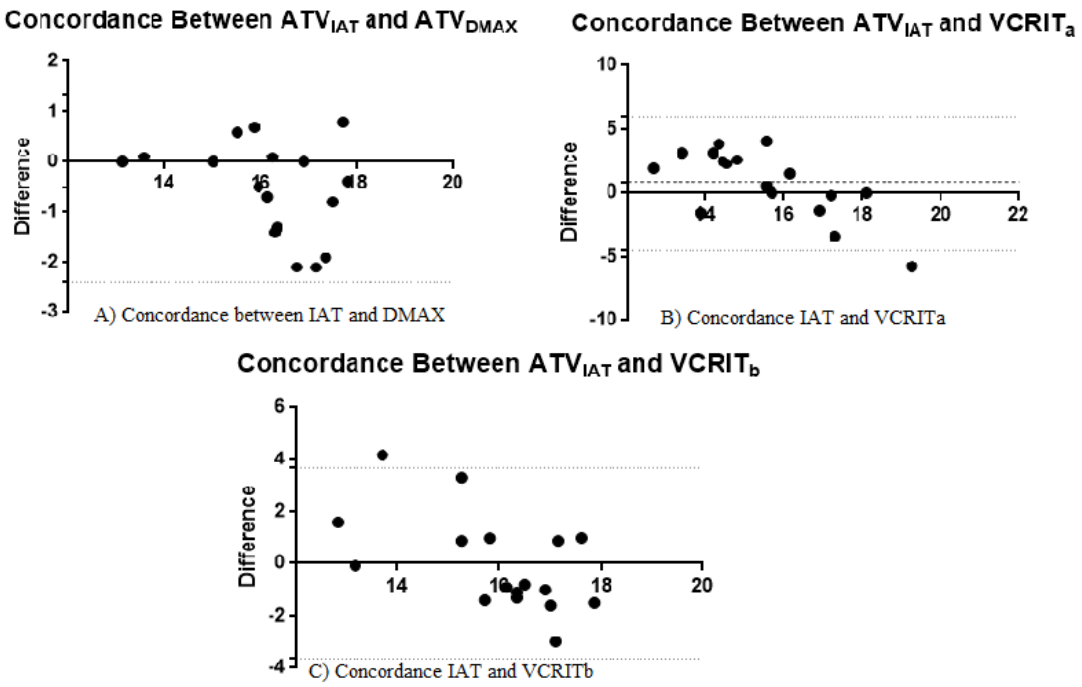

Figure 1: Concordance between the IAT and other methods

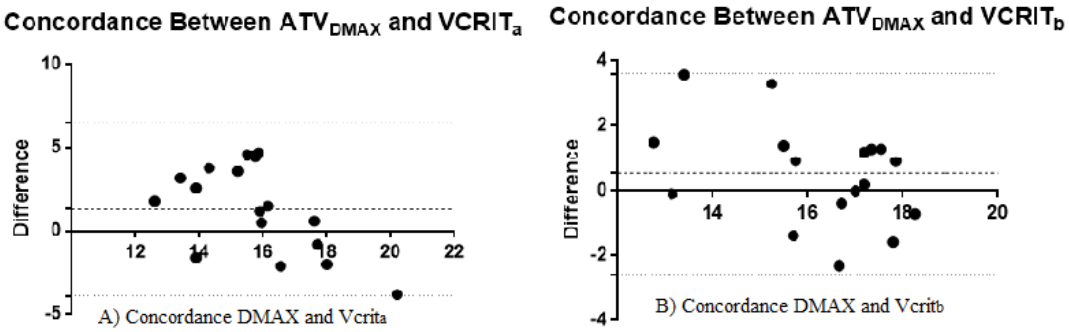

Figure 2 Concordance between the DMAX and other methods.

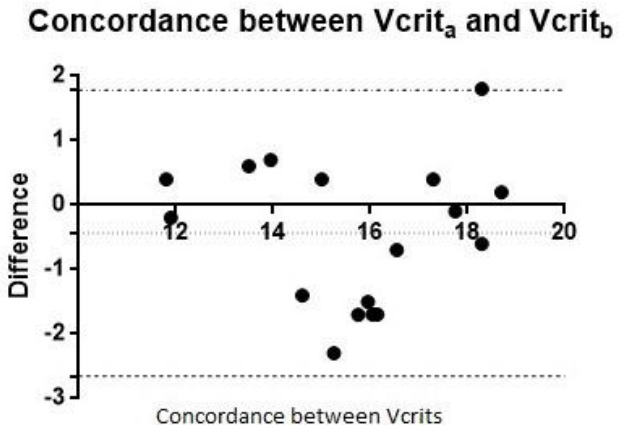

Figure 3: Concordance between VCrit$_a$ e a Vcrit$_b$

Table II. Correlations with variables

Variables	ATV_{IAT}	ATV_{Dmax}	$Vcrit_a$	$Vcrit_b$
ATV_{IAT}	XXXXXXXXXX	0.79**	0.49*	0.51*
ATV_{Dmax}	0.79**	XXXXXXXXXX	0.60**	0.67**
$Vcrit_a$	0.49*	0.60**	XXXXXXXXX	0.86**
$Vcrit_b$	0.51*	0.67**	0.86**	XXXXXXXX

**Correlation significance p< 0,01.

* Correlation significance p< 0,05

Table III. Comparison of AnTVs with methods.

Methods	**n**	**Velocity (Km/h)**	**% Max Velocity**	**Effect Size**
$AnTV_{IAT}$		15.92 ± 1.24	83.11	
$AnTV_{Dmax}$		16.44 ± 1.55	85.83	
$Vcrit_a$	17	15.47 ± 2.88	80.78	
$Vcrit_b$		15.90 ± 2.15	83.01	
	$AnTV_{IAT}$ - $AnTV_{Dmax}$	0.036*		0.97
	$AnTV_{IAT}$ - $Vcrit_a$	0.342		0.88
P	$AnTV_{IAT}$ - $Vcrit_b$	0.965		0.80
	$AnTV_{Dmax}$ X- $Vcrit_a$	0.035**		0.90
	$AnTV_{Dmax}$ - $Vcrit_b$	0.175		0.98
	$Vcrit_a$- $Vcrit_b$	0.138		0.97

* p < 0.5 difference ATV_{IAT} and $AnTV_{DMAX}$

** p < 0.5 difference ATV_{DMAX} and VCRITa

DISCUSSION

Returning to the aim of the study, we can conclude that methods show agreement among them and that they have a positive correlation. Currently, the literature seeks to describe more precise patterns for workload assessment and to compare AnT determination methods using metabolic parameters, such as lactate and indirect methods as Vcrit, which are extremely attractive for a prescription and control of training programs.

The transition thresholds found in the present study reflect the behavior already found in other studies, which show agreement between IAT and DMAX methods [12],[18]. Recent investigations have identified anaerobic speeds (AnTVs) close to 15.7 km/h [25],[26], similar to that found in our study, although the used protocol was performed in mat and not in the field, as in our study.

Aiming to clarify methods for identifying AnT, a study proposed three methods to identify AnT (increase of 0.5 $mmol.L^{-1}$, visual inspection, and log-log) of identification of lactate threshold in

cyclists. In the aforementioned study, the authors identified the same point of AnT indicating an r of 0.978, 0.992 and 0.977 for the methods visual inspection x 0.5 mmol.L^{-1}, visual inspection x log-log, and 0.5 mmol.L^{-1} x log-log, respectively [27]. These results corroborate with our study, where there of $AnTV_{IAT}$ x $AnTV_{DMAX}$ was 0.795.

In another line of thought to determine the AnT (9), it was sought to elucidate the use of a fixed lactate measurement for AnT/AnTV determination and control in runners, and verified that the fixed values of 3 mmol.L^{-1} and 4 mmol.L^{-1} are a simple and valid alternative to evaluate and control training in runners [28],[29] have pointed out in their respective revisions that despite different models for predicting this transition point, all represent the same physiological moment, and that mathematical methods are more accurate than visual methods, since they do not start from the premise of a subjective interpretation [12],[28] .

In line with the assertions of [3],[30], we found agreement and correlation between IAT and DMAX methods in our study, which reinforces the theory that different methods represent the same physiological moment. However, when comparing the speeds in which the AnT occurred, we identified significant differences, being the DMAX method superior to the IAT in 4%. These differences can be explained by the model used to identify the AnT by the IAT method where it proposes the increase greater than 0.5 mmol.L^{-1} among workloads can be defined as the AnT [11]. The methodological difference showed by methods may justify such discrepancy, which further emphasizes the need for procedures in which the subjectivity of the evaluators does not interfere on the result.

Another line that should be considered is the reliability of using Vcrit as a mean of training evaluation and control. In our study, we found agreement through the Bland-Altamn method and correlation in determined speeds through invasive methods ($AnTV_{IAT}$ and $AnTV_{DMAX}$) with $Vcrit_a$ and $Vcrit_b$. This meets the study finding a r of 0.84 when compared to an interval method to determine the AnTV [13]. These findings highlight the reliability of the noninvasive method of exercise prescription in moderately trained runners. A recent systematic review has raised the importance of the expression for critical power and/or critical velocity (Vcrit) and its application in sports, mainly due to the use of these variables in the prescription and control of the intermittent exercise of high intensity (19). As demonstrated in a study comparing the prescription of a training program on track and on treadmill, the latter has proven to be an effective method since controlled by indirect methods [31], [16].

Studies that have verified the reliability of Vcrit in the determination of AnT are found in the literature in swimming, cycling and running [13],[17],[31],[32]. The recent findings, emphasizing that the Vcrit can be considered a reliable method to determine the AnT in runners, regardless of the used distances and/or the invasive methods to determine the AnT.

A recent review on Vcrit indicates that the different methodologies to predict Vcrit may be a limiting factor and cause divergences among results found in the literature [17],[33],[34]. The authors further clarify some used methodologies to determine Vcrit: counter clock tests; prediction equations; relationship between two distances and time to estimate Vcrit; interval and submaximal methods; and fixed time test of 180 secs [35],[16]. Our study used the classical proposal that uses two distances and obtains a relationship with the run time in each distance. This methodology is performed in most of the runner studies, thus validating the use of the distance x time methodology in the determination of Vcrit [22]. The use of Vcrit in runners has been recommended in the literature in both trained and untrained subjects, which emphasizes its ecological validity [33],[36].

Conclusion: The study found that the estimated threshold velocities in the methods that used

blood lactate with the Vcrit are concordant and correlations among them, so the presented methods are safe for the training prescription.

The study shows a limitation, which is not proven by the AnTV found in the different methodologies with the gold standart method, which is the maximal lactate steady state (MLSS), in order to establish an even greater reliability in the found results.

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