RBCDH Revista Brasileira de CINEANTROPOMETRIA e Desempenho Humano

DOI: http://dx.doi.org/10.5007/1980-0037.2014v16n4p419

original article

Alternative methods for estimating maximum lactate steady state velocity in physically active young adults

Métodos alternativos para estimar a velocidade da máxima fase estável de lactato em adultos jovens fisicamente ativos

Yuri Lopes Motoyama[1]
Paulo Eduardo de Assis Pereira[1]
Gilmar de Jesus Esteves[1]
João Marcos Pereira Duarte[2]
Vitor Carlos Piubelli Carrara[2]
Gustavo Mello Rissato[2]
Paulo Henrique Silva Marques de Azevedo[3]

Abstract – The aim of this study was to compare the velocities found in the protocols used to measure the indirect individual anaerobic threshold (IAT_{ind}), glucose threshold (GT) and critical velocity (CV) with the gold standard, the maximum lactate steady state (MLSS) protocol. Fourteen physically active young adults (23±3.1 years; 72±10.97 kg; 176±7 cm; 21±5.36% body fat) performed a 3000-m track running test to determine IAT_{ind} using the prediction equation and an incremental test on a treadmill to determine GT. The CV was identified by linear regression of the distance-time relationship based on 3000-m and 500-m running performance. The MLSS was identified using two to five tests on different days to identify the intensity at which there was no increase in blood lactate concentration greater than 1 mmol/L between the 10th and 30th minute. A significant difference was observed between mean CV and MLSS ($P \leq 0.05$) and there was a high correlation between MLSS and IAT_{ind} ($R^2=0.82$; $P \leq 0.01$) and between MLSS and GT ($R^2=0.72$; $P \leq 0.01$). The Bland-Altman method showed agreement between MLSS and IAT_{ind} [mean difference -0.24 (confidence interval -1.72 to 1.24) km/h] and between MLSS and GT [0.21 (-1.26 to 1.29) km/h]. We conclude that the IAT_{ind} and GT can predict MLSS velocity with good accuracy, thus making the identification of MLSS practical and efficient to prescribe adequate intensities of aerobic exercise.

Key words: Anaerobic threshold; Blood glucose; Critical power; Exercise.

Resumo – *O objetivo do presente estudo foi comparar as velocidades encontradas nos protocolos de Limiar Anaeróbio Individual Indireto (LAI_{ind}), Limiar Glicêmico (LG) e Velocidade Crítica (VC) com o padrão ouro, o protocolo de identificação da máxima fase estável do lactato (MFEL). Participaram 14 adultos jovens fisicamente ativos (23±3,1 anos; 72±10,97 kg; 1,76±0,07 m; 21±5,36 % gordura corporal) que realizaram um teste de 3000m em pista para determinar o LAI_{ind} através de equação de predição; teste incremental em esteira ergométrica para determinação do LG; a VC foi identificada por regressão linear através da relação distância-tempo com base no desempenho em corridas nas distâncias de 3.000m e 500m; a MFEL foi identificada utilizando de dois a cinco testes em dias distintos até encontrar a intensidade onde não houve aumento da concentração de lactato sanguíneo maior que 1 mmol.L^{-1} entre os minutos 10 e 30. Houve diferença estatística entre os valores médios da VC e a MFEL ($P \leq 0,05$), elevada correlação entre MFEL e LAI_{ind} ($R^2=0,82$; $P \leq 0.01$) e MFEL e LG ($R^2=0,72$; $P \leq 0.01$). Através do método Bland-Altman foram encontradas as concordâncias entre MFEL e LAI_{ind} [diferença média -0,24 (intervalo de confiança -1,72 a 1,24) km/h] e MFEL e LG [0,21 (-1,26 a 1,29) km/h]. Concluímos que o LAI_{ind} e o LG são testes que podem predizer com boa precisão a velocidade da MFEL, tornando sua identificação prática e eficiente para prescrição de intensidades adequadas para o treinamento aeróbio.*

Palavras-chave: *Exercício; Glicemia; Limiar anaeróbio; Potência Crítica.*

1 Universidade Federal de São Paulo. Programa de Pós-Graduação Interdisciplinar em Ciências da Saúde. Grupo de Estudos e Pesquisas em Fisiologia do Exercício. Santos, SP. Brasil.

2 Faculdade Anhanguera de Bauru. Grupo de Estudos e Pesquisas em Fisiologia do Exercício. Santos, SP. Brasil.

3 Universidade Federal de São Paulo. Programa de Pós-Graduação Interdisciplinar em Ciências da Saúde. Departamento de Ciências do Movimento Humano. Grupo de Estudos e Pesquisas em Fisiologia do Exercício. Santos, SP. Brasil.

Received: 04 July 2013
Accepted: 24 September 2013

Licence
Creative Commom

INTRODUCTION

The maximum lactate steady state (MLSS) is defined as the exercise intensity at which a dynamic metabolic balance exists between maximum lactate production and maximum lactate removal. The corresponding workload can be maintained for a prolonged period of time in the absence of continuous accumulation of lactate in the bloodstream. The velocity corresponding to the MLSS is a key factor for the evaluation of endurance training and provides positive results when its intensity is used for training prescription in physically active individuals[1,2].

One of the methods used to determine MLSS consists of performing 30-minute exercise tests on different days at intensities ranging from 50-90% VO_2max[3]. However, other authors have used less invasive methods for the determination of MLSS that do not require blood collection or only a small number of blood samples[4]. Protocols that are less time consuming and that optimize the prediction of MLSS use alternatives such as the glucose threshold (GT)[5], critical velocity (CV)[6], and indirect individual anaerobic threshold (IAT_{ind})[7]. In addition to their relevant cost-benefit relationship, these protocols are practical because they can be applied on ergometers, require little space, and can be used in different populations[8-10]. Several studies have proposed alternative methods for estimating MLSS; however, the results are conflicting and few studies involve non-athletes.

The aim of the present study was to compare the velocities obtained with different protocols (GL, CV and IAT_{ind}) with the MLSS velocity in non-athletes.

METHODOLOGICAL PROCEDURES

This was a cross-sectional, prospective and quantitative study. After anthropometric assessment, all participants performed three tests: 1) two track tests to determine CV; 2) one test on a treadmill to determine GT velocity, and 3) one test on a treadmill to determine MLSS velocity. All tests were performed at an interval of 48 to 72 hours.

Participants

Fourteen healthy men without any physical or clinical exercise restriction volunteered to participate in the study. The participants were non-athlete, university students recruited on the campus of a university in Bauru, São Paulo, Brazil (23 ± 3.1 years; 72 ± 10.97 kg; 1.76 ± 0.07 m; 21 ± 5.36% body fat). The procedures, risks and benefits of the study were explained to the participants before they signed the free informed consent form. The experimental procedures were approved by the local Ethics Committee (Permit No. 32/2008).

Study design

On the first visit to the laboratory, the height, body weight and skinfolds of the participants were measured. Body density was estimated using the 3-site skinfold protocol proposed by Pollock[11] and the equation of Siri[12] for assessing body composition. All subjects were asked not to perform any strenuous physical activity 48 hours prior to the tests.

The sample size was estimated using the table proposed by Hulley[13], considering an alpha value (two-sided) of 0.05, beta error of 0.05, and expected correlation coefficient of r=0.80.

The experiment consisted of two initial tests on a running track to determine CV, one test on a treadmill to determine GT, and another test to determine MLSS. The IAT_{ind} was calculated using the following formula:

$$IAT_{ind} = (V3000*0.97) - 15.81,$$

where V3000 is the mean velocity (m/min) achieved in the initial 3000-m test.

The tests were performed on a treadmill (Movement LX-150) and on a running track with charcoal flooring and 100-m marks. The subjects were asked to have their meals 3 hours before the tests.

Test 1

A linear model of the distance-time relationship obtained based on the 3000-m and 500-m running performance on the track was used to determine CV. The slope of the linear regression line defined the value of CV[14].

Test 2

For the determination of GT, the subject was submitted to an incremental test on a treadmill (Movement LX-150) at an inclination of 1%[15] and initial velocity of 65% of V3000, followed by increments of 0.5 km/h at intervals of 3 minutes in each stage. There was an interval of 30 seconds in each stage for blood collection from the ear lobe. The GT was defined as the velocity when glucose levels were minimal during the test[8]. Blood glucose was measured with the OneTouch Ultra-2® glucose meter (Johnson & Johnson®) and is expressed as mg/dL.

Test 3

Two to five 30-minute tests were performed for the determination of MLSS. In the first test, a velocity that was 5% below the GT obtained in the previous test was used. Subsequently, the velocity was increased by 5% in each test until the increase in lactate was higher than 1 mmol/l between the 10th and 30th minute, considering the previous velocity as the corresponding MLSS[16]. The tests were separated by resting intervals of 48-72 hours.

Blood collection and analysis

Blood samples were collected with a disposable lancet by puncture of the ear lobe, previously disinfected with alcohol, using disposable gloves. The blood was collected into heparinized capillary tubes calibrated to contain 25 µL arterial blood and the tubes were transferred to Eppendorf tubes containing 50 µL 1% sodium fluoride. Before the collection of each sample, the site was cleaned to prevent contamination with sweat or other materials that would make the blood samples unusable. All samples were stored in a freezer for subsequent analysis. Blood lactate concentrations were measured with a lactate analyzer based on an electroenzymatic method (YSI 1500 Sports, Yellow Springs Instruments, OH, USA) and are expressed as mmol/L.

Statistical analysis

First, the data were submitted to descriptive analysis (mean ± standard deviation). Analysis of variance for repeated measures was used to determine possible differences in IAT_{ind}, GT, CV and MLSS velocity. Correlations between IAT_{ind}, GT, CV and MLSS were estimated using Pearson's correlation test. A level of significance of $P \leq 0.05$ was adopted. Bland-Altman analysis was used to evaluate the agreement between methods. Statistical analysis was performed using the Statistical Package for the Social Sciences 17.0 (SPSS) and Bland-Altman plots were constructed using the Medcalc 12.3.0.0 program (both for Windows).

RESULTS

The overall results of the parameters studied are shown in Table 1. A significant difference was observed between mean CV and MLSS ($P \leq 0.05$).

Despite the high correlation between all methods used to estimate MLSS, Bland-Altman analysis revealed agreement only between MLSS and IAT_{ind} [mean difference -0.24 (confidence interval -1.72 to 1.24) km/h] and MLSS and GT [0.21 (-1.26 to 1.29) km/h] (Figure 1). The mean (± standard deviation) lactate concentration in the MLSS test was 5 ± 1.8 mmol/L.

Table 1. Critical velocity (CV), estimated individual anaerobic threshold (IATind) velocity, glucose threshold (GT) velocity, and maximum lactate steady state (MLSS) velocity, expressed as km/h.

	CV	IAT_{ind}	GT	MLSS
Mean	10.23	9.69	9.24	9.45 *
SD	1.68	1.66	1.41	1.22

A correlation of 0.91 was observed between IAT_{ind} and MLSS (R^2=0.82; $P \leq 0.01$), of 0.85 between GT and MLSS (R^2=0.72; $P \leq 0.01$), and of 0.90 between CV and MLSS (R^2=0.82; $P \leq 0.01$). All parameters showed a high correlation with MLSS velocity.

DISCUSSION

Conventional statistical approaches have shown the absence of significant differences between the MLSS, IAT_{ind} and GT methods. This suggests that the IAT_{ind} and GT methods can be used to estimate MLSS. In contrast, CV was not a good predictor of MLSS, as indicated by the significant difference between MLSS and CV, overestimating MLSS despite the observation of a good correlation.

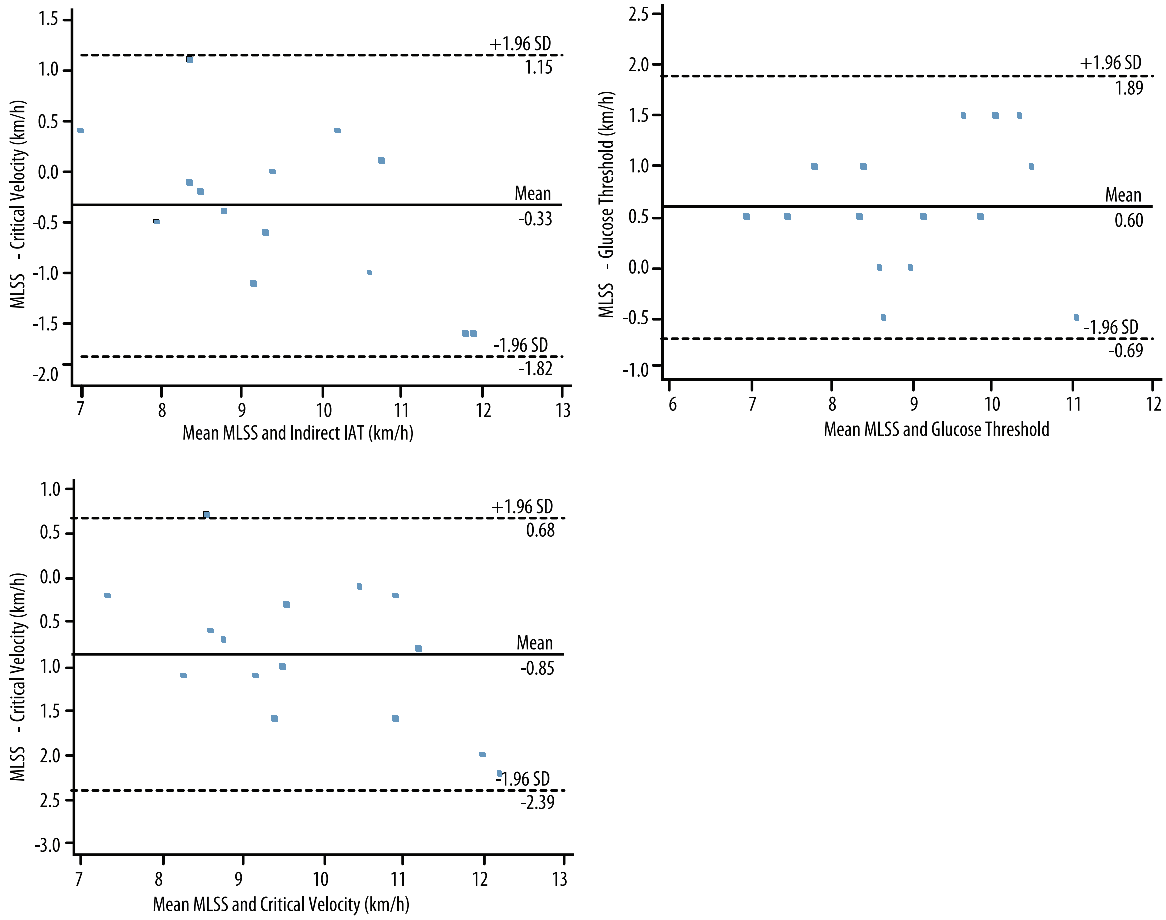

Figure 1. Bland-Altman plots of agreement between MLSS and mean IATind, GT and CV velocities. Continuous lines indicate the mean differences and dashed lines indicate the 95% limits of agreement between measures.

During high-intensity activities, lactate accumulation is due to production being higher than its removal[17]. The MLSS is a measure of the exercise intensity at which a dynamic balance exists between maximum lactate production and maximum lactate removal[3,17]. It can be defined as the highest lactate concentration in blood and its respective workload can be maintained over time without continuous blood lactate accumulation[1,3,18]. The MLSS is an individual indicator of exercise intensity[19] and is therefore important for the prescription, monitoring and evolution of aerobic exercise intensity[1]. However, the protocol used to identify the MLSS requires that the participants are available for 2 to 6 constant workload tests at different intensities on different days, with each test lasting 30 minutes. This procedure is not feasible for participants enrolled in a training program and researchers often do not have the time or material needed for the tests. Therefore, investigators have tried to develop methods to optimize the estimation of MLSS[20-22].

Simões et al.[23] proposed an indirect test to estimate MLSS in endurance runners based on the linear relationship between mean 3-km running velocity and velocity at the individual anaerobic threshold. The data obtained in the present study suggest that the method proposed by Simões et al.[23] is suitable to estimate the intensity associated with MLSS in physically active subjects. No significant difference was observed between the velocity at IAT_{ind} and MLSS (Figure 1) and the methods showed a high correlation (r=0.91; R^2=0.82; $P\leq0.01$) and agreement [-0.24 (-1.72 to 1.24) km/h]. These results suggest that MLSS can be estimated safely based on a single 3000-m run on a running track, thus providing a faster and noninvasive procedure that does not requires expenses with materials.

There was also no significant differences between the velocities at GT and MLSS, with the observation of a high correlation (r=0.85; R^2=0.72; $P\leq0.01$) and agreement [0.21 (-1.26 to 1.69) km/h]. In view of the easy execution and low cost of the identification of GT, this test also has great practical applicability. Sotero et al.[8] found a high correlation (r=0.96; $P\leq0.01$) and agreement [1.7 (8.5) m/min] between GT and MLSS, indicating that blood glucose concentration is a good predictor of MLSS in physically active subjects.

Many of the studies estimating MLSS based on the CV have obtained values that overestimated MLSS, a fact indicating that this method is not adequate for the estimation of MLSS[4,24,25]. Other factors that support the low accuracy of CV in estimating MLSS are the fact that the intensity determined for CV may vary depending on the distance covered[26] and that the mathematical model used for the determination of CV shows a variation of 18%[27]. Taken together, the results suggest that the model of CV used in this study is not adequate to estimate MLSS in physically active young male subjects.

One important limitation of this study was the application of the test to estimate CV on a track, considering the technical differences between running on a treadmill and on a track. The alternative protocols used for the determination of MLSS have advantages and disadvantages. According to Azevedo et al.[28], the protocol applied should taken into consideration the methodology used, experience of the examiner, and population studied. However, the use of methods such as IAT^{ind} and GT has a high practical value, considering the importance of identifying the second threshold for training prescription.

CONCLUSION

The present results permit us to conclude that MLSS can be estimated in young and physically active subjects using IAT_{ind} and GT. Both methods were found to be a good option for the determination and prescription of exercise intensities, particularly aerobic exercise. However, the present results showed that CV is not a valid method to estimate MLSS.

ACKNOWLEDGEMENTS
We thank Prof. Victor Zuniga Dourado for his intellectual contribution to this article.

REFERENCES

1. Philp A, Macdonald AL, Carter H, Watt PW, Pringle JS. Maximal lactate steady state as a training stimulus. Int J Sports Med 2008;29(6):475-9.

2. Baldwin J, Snow RJ, Febbraio MA. Effect of training status and relative exercise intensity on physiological responses in men. Med Sci Sports Exerc 2000;32(9):1648-54.
3. Faude O, Kindermann W, Meyer T. Lactate threshold concepts: how valid are they? J Sports Med 2009;39(6):469-90.
4. Smith CG, Jones AM. The relationship between critical velocity, maximal lactate steady-state velocity and lactate turnpoint velocity in runners. Eur J Appl Physiol 2001;85(1):19-26.
5. Simões HG, Campbell CS, Kokubun E, Denadai BS, Baldissera V. Blood glucose responses in humans mirror lactate responses for individual anaerobic threshold and for lactate minimum in track tests. Eur J Appl Physiol Occup Physiol 1999;80(1):34-40.
6. Machado MV, Júnior OA, Marques AC, Colantonio E, Cyrino ES, De Mello MT. Effect of 12 weeks of training on critical velocity and maximal lactate steady state in swimmers. Eur J Sport Sci 2011;11(3):165-70.
7. Simões HG, Denadai BS, Baldissera V, Campbell CS, Hill DW. Relationships and significance of lactate minimum, critical velocity, heart rate deflection and 3 000 m track-tests for running. J Sports Med and Phys Fit 2005;45(4):441.
8. Sotero RC, Pardono E, Landwehr R, Campbell CSG, Simoes HG. Blood glucose minimum predicts maximal lactate steady state on running. Int J Sports Med 2009;30(09):643-6.
9. Rocha C, Canellas A, Monteiro D, Antoniazzi M, Azevedo PHSM. Changes in Individual Glucose Threshold during Military Training. Int J Sports Med 2010;31(7):482-5.
10. Simões HG, Hiyane WC, Benford RE, Madrid B, Prada FA, Moreira SR, et al. Lactate threshold prediction by blood glucose and rating of perceived exertion in people with type 2 diabetes. Percept Mot Skills 2010;111(2):365.
11. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. Br J Nutr. 1978;40(03):497-504.
12. Siri WE. Body composition from fluid spaces and density: analysis of methods. In: (Eds.) JBaAH, editor. Techniques for Measuring Body Composition. Washington, DC: National Academy of Sciences/National Reserach Council; 1961. p. 223-4.
13. Hulley SB, Cummings SR, Browner WS, Grady DG, Newman TB. Designing clinical research: Lippincott Williams & Wilkins; 2006.
14. Hill DW. The critical power concept: a review. Sports Med. 1993;16(4):237-54.
15. Jones AM, Doust JH. A 1% treadmill grade most accurately reflects the energetic cost of outdoor running. J Sports Sci 1996;14(4):321-7.
16. Beneke R, Duvillard SP. Determination of maximal lactate steady state response in selected sports events. Med Sci Sports Exerc. 1996;28(2):241.
17. Billat VL, Sirvent P, Py G, Koralsztein JP, Mercier J. The concept of maximal lactate steady state: a bridge between biochemistry, physiology and sport science. Sports Med 2003;33(6):407-26.
18. Cairns SP. Lactic acid and exercise performance: culprit or friend? Sports Med 2006;36(4):279-91.
19. Beneke R, Hütler M, Leithäuser RM. Maximal lactate-steady-state independent of performance. Med Sci Sports Exerc 2000;32(6):1135.
20. Moreira SR, Simões GC, Hiyane WC, Campbell CSG, Simões HG. Identificação do limiar anaeróbio em indivíduos com diabetes tipo-2 sedentários e fisicamente ativos. Rev Bras Fisioter 2007;11(4):289-96.
21. Figueira TR, Denadai BS. Relações entre o limiar anaeróbio, limiar anaeróbio individual e máxima fase estável de lactato em ciclistas. Rev Bras Cien Mov 2004;12(2):91-5.
22. de Oliveira JC, Baldissera V, Simões HG, Perez SEA, de Aguiar AP, de Azevedo PHSM, et al. Identificação do limiar de lactato e limiar glicêmico em exercícios resistidos. Rev Bras Med Esporte 2006;12(6):333-8.

23. Simões HG, Campbell CSG, Kokubun E, Denadai BS, Baldissera V. Indirect assessment of anaerobic threshold in track test for endurance runners. Abstract book of the International Pre-Olympic Scientific Congress. 1996;Annals:55.
24. Martin L, Whyte GP. Comparison of critical swimming velocity and velocity at lactate threshold in elite triathletes. Int J Sports Med 2000;21(5):366.
25. Brickley G, Doust J, Williams C. Physiological responses during exercise to exhaustion at critical power. Eur J Appl Physiol 2002;88(1):146-51.
26. Greco CC, Denadai BS, Pellegrinotti I, Freitas AB, Gomide E. Limiar anaeróbio e velocidade crítica determinada com diferentes distâncias em nadadores de 10 a 15 anos: relações com a performance ea resposta do lactato sanguíneo em testes de endurance. Rev Bras Med Esporte 2003;9(1):2-8.
27. Hill DW, Ferguson CS. A physiological description of critical velocity. Eur J Appl Physiol Occup Physiol 1999;79(3):290-3.
28. Azevedo PHSM, Garcia A, Duarte JMP, Rissato GM, Carrara VKP, Marson RA. Limiar Anaeróbio e Bioenergética: uma abordagem didática. Rev Educ Fís/UEM 2009;20(3):453-64.

Corresponding author

Paulo Henrique Silva Marques de Azevedo,
Rua Silva Jardim, 136.
Vila Mathias.
CEP 11.015-020 – Santos, SP. Brasil
E-mail: paulohazevedo@yahoo.com.br