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Original Article (short paper)

Comparison of methods to determine the lactate threshold during leg press exercise in long-distance runners

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Abstract - Aims: To determine lactate threshold (LT) by three different methods (visual inspection, algorithmic adjustment, and Dmax) during an incremental protocol performed in the leg press 45° and to evaluate correlation and agreement among these different methods. **Methods:** Twenty male long-distance runners participated in this study. Firstly, participants performed the dynamic force tests in one-repetition maximum (1RM). In the next session, completed an incremental protocol consisted of progressive stages of 1 min or 20 repetitions with increments of 10, 20, 25, 30, 35, and 40% 1RM. From 40% 1RM, increments corresponding to 10% 1RM were performed until a load in which the participants could not complete the 20 repetitions. A rest interval of 2 min was observed between each stage for blood collection and adjustment of the workloads for the next stage. **Results:** Our results showed no significant difference in relative load (% 1RM), good correlations, and high intraclass correlation coefficients (ICC) between algorithmic adjustment and Dmax ($p = 0.680$, r = 0.92; ICC = 0.959), algorithmic adjustment and visual inspection ($p = 0.266$, r = 0.91; ICC = 0.948), and Dmax and visual inspection ($p = 1.000$, r = 0.88; ICC = 0.940). In addition, the Bland-Altman plot and linear regression showed agreement between algorithmic adjustment and Dmax ($r^2 = 0.855$), algorithmic adjustment and visual inspection ($r^2 = 0.834$), and Dmax and visual inspection ($r^2 = 0.781$). **Conclusion:** The good correlation and high agreement among three methods suggest their applicability to determine LT during an incremental protocol performed in the leg press 45°. However, the best agreement found between mathematical methods suggests better accuracy.

Keywords: resistance training, anaerobic threshold, visual inspection, algorithmic adjustment, Dmax.

Introduction

The maximal lactate steady state (MLSS) is considered a physiological benchmark for the evaluation and prescription of endurance training intensities[1]. A method used to estimate MLSS is the blood lactate concentrations (BLa)[2], called lactate threshold (LT), determined at the highest constant workload, in which during a maximal incremental protocol[3] is achieved a maximum balance between lactate production and their clearance rates in the blood[4-6].

Currently, some literature reviews have suggested that resistance training can improve running economy, muscle power, and performance in long-distance running[7,8]. In this line, Sedano, Marín, Cuadrado, and Redondo[9] found significant performance improvements in long-distance runners who performed concurrent training, i.e., resistance training with 40% 1RM combined with traditional endurance training. A literature review highlighted that resistance training performed at LT intensity can lead to simultaneous improvements in cardiorespiratory endurance and muscle strength[10]. Thus, it seems that the combination of traditional endurance training and resistance training may be an interesting training strategy for the long-distance runners[7-9].

Traditionally, two or more constant load tests are considered as the "gold standard" for the MLSS determination in cyclic exercises[6]. However, due to the time-consuming during evaluations[5,6], these tests are replaced by single session tests[5,6], presenting validity and reproducibility[3]. Although some studies have already verified a steady-state in resistance training performed at LT intensity[11,12], LT is generally estimated through the visual inspection method[2,13,14] and mathematical models[11,12,15].

The LT determination in resistance training follows the same parameters used during cyclic exercises, in which BLa are firstly plotted as a function to the exercise intensities or workloads. In the visual inspection method, experienced researchers determine LT at workload in which BLa begins to increase exponentially[14,16]. The algorithmic adjustment method uses two linear regression segments assigning the point of intersection between these two segments as LT[11,12,17]. The Dmax method developed by Cheng et al.[18], LT is determined in the longest perpendicular distance between the curve originating by third-order polynomial adjustment and the linear regression line[15]. However, when mathematical models were compared to the visual analysis method, some discrepancies are verified in the workload in which LT was determined[19], causing doubts about which model to adopt for the resistance training prescription.

Thus, considering that the use of mathematical algorithms can facilitate, automate and/or semi-automate of LT detection[19] when compared to the visual inspection method, the main aim of this study was to determine LT by three different methods (visual inspection, algorithmic adjustment, and Dmax) during an incremental protocol performed in the leg press 45° and to evaluate the correlation and agreement among the different proposed methods.

Methods

Participants

Twenty male long-distance runners ([mean ± SD] age = 29.2 ± 3.2 years; relative body fat = 11.33 ± 2.62%; height = 1.74 ± 0.10 m; body mass = 75.44 ± 4.38 kg; time of 5,000 m = 23 min and 37.8 s ± 2 min and 21 s; V_{max} = 15.26 ± 2.32 km.h^{-1}; 1RM leg press 45° = 369 ± 20 kg; training time = 2.46 ± 0.62 years) were recruited to participate in the study. The sample dimension analysis was performed using G-Power package[20], under a framework assuming an estimation error of $\alpha = 0.05$, power = 90% (required effect size = 0.35), having 3 measures (methods), an (n = 19) was necessary to reach statistical power of 90.4%. Participants should meet the following criteria to be included in the research: (A) absence of bone, muscle, and cardiovascular pathologies; (B) regularly participation in long-distance running on the road competing at 5,000 m and 10,000 m; and c) previous experience in the leg press 45° and have performed such exercise at some moment in their sports season. Before the beginning of procedures, an approval opinion was obtained through the local ethics committee (CAAE: 53675416.3.0000.5148) in accordance with the Declaration of Helsinki. Posteriorly, participants signed a consent form for their participation in the study.

Experimental design

To verify the effect of incremental loading protocol on blood lactate responses during leg press 45°, we established four individual test sessions separated by a 48-h interval. To perform these sessions, we previously instructed participants to abstain from vigorous physical exercises and to avoid alcohol and caffeinated beverages 48-h interval before the tests. In the first session, participants received previous instructions on all procedures that would be adopted during the tests and we evaluated them concerning body mass, height, and fat mass. In the second and third sessions, participants performed the dynamic force test and retest in one-repetition maximum (1RM). In the fourth session, we randomized the participants to collect blood samples during the incremental protocol of loads performed in the leg press 45°.

Anthropometric evaluation

For the sample characterization, we collect the data of height and body mass through a scale with a stadiometer (110 FF, Welmy®, Santa Bárbara d'Oeste, Brazil). We estimated the fat percentage using a bioimpedance device (Quantum BIA-II, RJL Systems®, Clinton Township, USA). Electrodes used for the collection were tetrapolar type (Bio Tetronic, Sanny®, São Bernardo do Campo, Brazil).

Dynamic force test at one-repetition maximum

The 1RM protocol followed the recommendations proposed by National Strength and Conditioning Association[21]. The 1RM test was applied after a warm-up series with lighter loads performed in the specific exercise. The first attempt corresponded to 50% of the estimated 1RM based on the load conventionally used by participants to perform their training between 8 and 10 maximum repetitions in the leg press 45°. Thereafter, participants had about 2 and 4 min of passive recovery until they felt fully recovered from the previous attempt. Based on the previous attempt and considering participant's and evaluator's perception the weight was changed in every exercise performed. The determination of 1RM lasted up to five attempts with all procedures being equally adopted during the 1RM test and retest.

Incremental protocol in the leg press 45°

For the incremental protocol in the leg press 45°, we randomized participants to perform progressive stages of 1 min with a total of 20 repetitions. The incremental protocol was performed at relative intensities of 1RM starting from 10% with the workload being progressively increased at the end of each stage to 20, 25, 30, 35, and 40% 1RM. From 40% 1RM, increments of 10% 1RM were performed until the participants could not complete the 20 predicted repetitions for each stage[11,19]. A rest interval of 2 min was observed between each stage for blood collection and adjustment of the workloads for the next stage[11,19]. The movement was controlled through a digital goniometer (GN360, Miotec® Equipamentos Biomédicos Ltda, Porto Alegre, Brazil) and movement speed was controlled through a digital metronome (DM90, Seiko®, Tokyo, Japan), being adopted 1 s for the concentric phase and 2 s for the eccentric phase, totaling 3 s or 1 repetition[11,19]. Within the incremental protocol, the equipment was adjusted to the participants with the trunk horizontally tilted at 45° and knees and hips flexed at 90°, with the movement knees and hips extended and returned to the initial position after flexion. During the test leg press 45° and diverse weight plates (Physicus®, Auriflama, Brazil) were used.

Blood lactate collection

A blood sample was collected by a puncture in the earlobe 1 min after each stage in the LP 45°, by a trained technician after asepsis using lancets (Accu-Chek Safe-T-Pro Uno, Roche®, Hawthorne, USA) and disposable gloves (Cremer®, Blumenau, Brazil). The first drop of blood was discarded and 25 µL of capillary blood was collected shortly thereafter using reagent strips for collection (Accusport BM - lactate, Roche®, Hawthorne, USA). A validated and reliable portable lactate analyzer (Accusport, Boehringer Mannheim - Roche®, Hawthorne, USA) was used[22] and calibrated with different standard solutions of known lactate concentrations (2, 4, 8, and 10 $mmol.L^{-1}$) before the tests.

Determination of lactate threshold by visual method

To determine the LT by visual inspection (LT_V), the lactate curves were plotted individually for each participant and two independent researchers performed the analysis of these curves. In case of a discrepancy between them, the evaluation of a third researcher was requested. We defined the LT_V as the exercise intensity in which Bla began to increase exponentially[14,16] (Figure 1A).

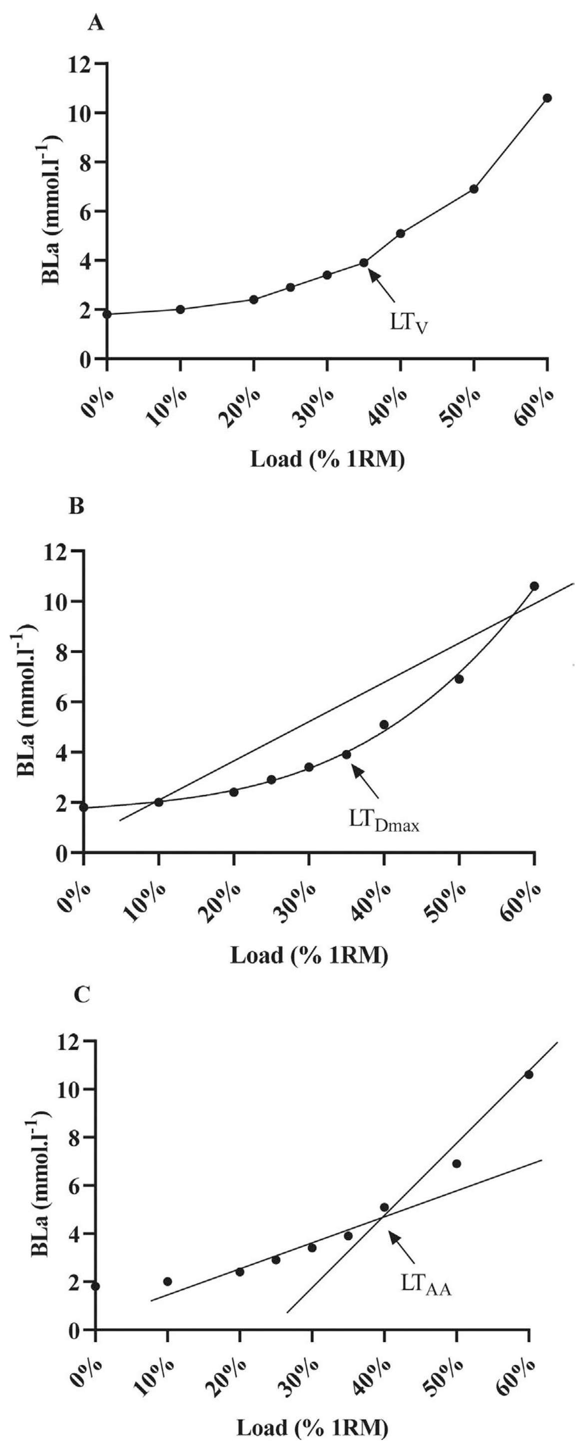

Figure 1 - Determination of LT by inspection visual method (Figure 1A), Dmax method (Figure 1B), and algorithm adjustment method (Figure 1C) during incremental protocol performed in the leg press 45°. The data refer to one of the participants.

Determination of lactate threshold by Dmax method

The LT was determined by means of individual plots, with BLa being plotted as a function of exercise intensities through the mathematical model Dmax

(LT_{Dmax}). Subsequently, a third-order polynomial adjustment was performed through a linear regression using the two extremes of the curve. We defined LT_{Dmax} as the point of greatest distance obtained perpendicularly from the line originated by the linear regression and the curve of the polynomial equation[18] generated with MATLAB software (9.0, MathWorks, Natick, MA, USA) (Figure 1B).

Determination of lactate threshold by algorithm adjustment

The LT was performed according to the procedures proposed by Orr, Green, Hughson, and Bennet[17] through the algorithm adjustment method (LT_{AA})[19]. The LT was determined through computerized two-segment linear regression by fixing the two linear regression equations emerging for each segment at the point of intersection between a plot of blood lactate concentration and relative intensity. For the calculation we used the MATLAB software (9.0, MathWorks, Natick, MA, USA) (Figure 1C).

Statistical analysis

To verify the normality and homogeneity of the variances Kolmogorov-Smirnov and Levene tests were adopted. Attended the assumptions of normality, homogeneity of variances, and sphericity, the One-Way ANOVA test of repeated measurements with Bonferroni's Post-Hoc was applied to compare LT_V, LT_{Dmax}, and LT_{AA} in the relative load (%1RM). Pearson's test and intraclass correlation coefficient (ICC) were applied to verify the correlation and reproducibility among the LT_V, LT_{Dmax}, and LT_{AA}. The correlation interpretation followed the classification criteria proposed by Hinkle, Wiersma and Jurs[23]: 0 - 0.3 negligible; 0.3 - 0.5 weak; 0.5-0.7 moderate; 0.7-0.9 strong and 0.9-1.0 very strong. The ICC was determined from the following classification criteria: < 0.4 poor; 0,4 - < 0,75 satisfactory; ≥ 0.75 excellent, proposed by Rosner[24]. To evaluate the agreement among LT_V, LT_{Dmax}, and LT_{AA} the visual analysis of the Bland-Altman plot[25] and linear regression analysis were used, being considered a bias of 5%. As statistical evidence, the significance level (α) of 5% was adopted, being the statistical analyses performed with SPSS software (25.0, IBM, Armonk, USA) and figures performed with Prism8 Software (GraphPad®, San Diego, USA).

Results

ICCs for the 1RM test-retest was between 0.940 and 0.960, being classified as excellent. Our results did not show significant difference in the relative load (% 1RM) between LT_{AA} and LT_{Dmax} (p = 0.680), LT_{AA} and LT_V (p = 0.266), and LT_{Dmax} and LT_V (p = 1.000). The ICC was classified as excellent between LT_{AA} and LT_{Dmax}, LT_{AA} and LT_V, and LT_{Dmax} and LT_V.

Visual analysis of the Bland-Altman plot during leg press 45º in relative load (% 1RM) demonstrated agreement between LT_{AA} and LT_{Dmax} (Figure 2A), LT_{AA} and LT_V (Figure 2B), LT_{Dmax} and LT_V (Figure 2C), with 95% of data being within the confidence interval ± 1.96.

Linear regression analysis plot during leg press 45º in relative load (% 1RM) demonstrated a strong relationship LT_{AA} and LT_{Dmax} (Figure 3A), LT_{AA} and LT_V (Figure 3B), LT_{Dmax} and LT_V (Figure 3C).

Discussion

The findings of the present study showed no statistical difference in relative load (% 1RM) where LT was determined among three different methods (visual inspection, algorithmic adjustment, and Dmax) during the incremental protocol performed in the leg press 45°. Moreover, visual inspection, algorithmic adjustment, and Dmax methods showed correlation and agreement for LT determination.

Mechanisms responsible for LT occurrence in incremental protocol performed in resistance exercise can be partially elucidated by hemodynamic and physiological factors[11] that are more prominent as the external load is increased[14,26] and hence the intensity of effort increases. In this respect, some studies have demonstrated that exercise intensities above 30% 1RM[11,14,16,19,27] induced increased muscle tension, specifically during the concentric phase of contraction, compressing the peripheral vascular system[28] and causing a reduction in perfusion flow to the active musculature[13,28]. This event collapses

Table 1 - Mean values (± SD) relationship of relative load (% 1RM) among the LT_{AA}, LT_{Dmax}, and LT_V.

Relative load (% 1RM)	Relative load (% 1RM)	Correlation	Correlation classification	Correlation significance	ICC
LT_{AA}	**LT_{Dmax}**				
34.08 ± 5.62	33.42 ± 6.04	r = 0.92*	Very strong	p = 0.001	0.959
LT_{AA}	**LT_V**				
34.08 ± 5.62	33.05 ± 6.15	r = 0.91*	Very Strong	p = 0.001	0.948
LT_{Dmax}	**LT_V**				
33.42 ± 6.04	33.05 ± 6.15	r = 0.88*	Strong	p = 0.001	0.940

p< 0.01* correlation between LT_{AA} and LT_{Dmax}, LT_{AA} and LT_V, and LT_{Dmax} and LT_V.

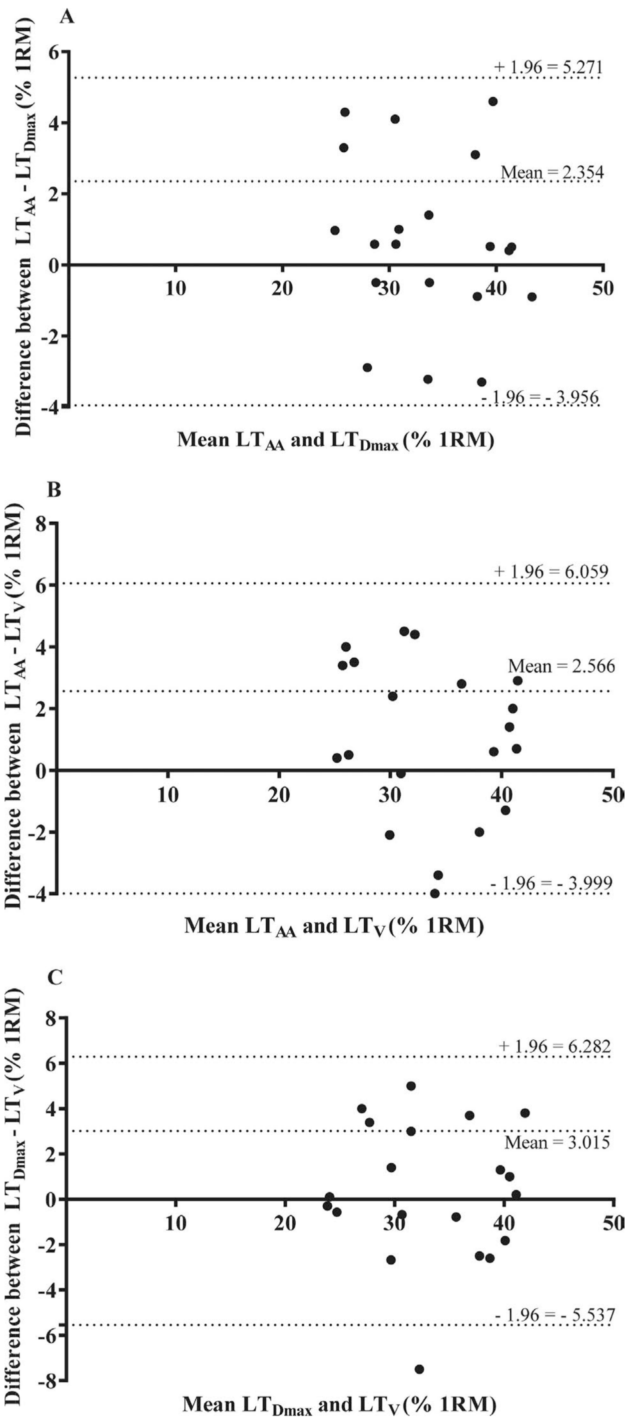

Figure 2 - Agreement between LT_V and LT_{Dmax} (Figure 2A), LT_V and LT_{AA} (Figure 2B), and LT_{Dmax} and LT_{AA} (Figure 2C).

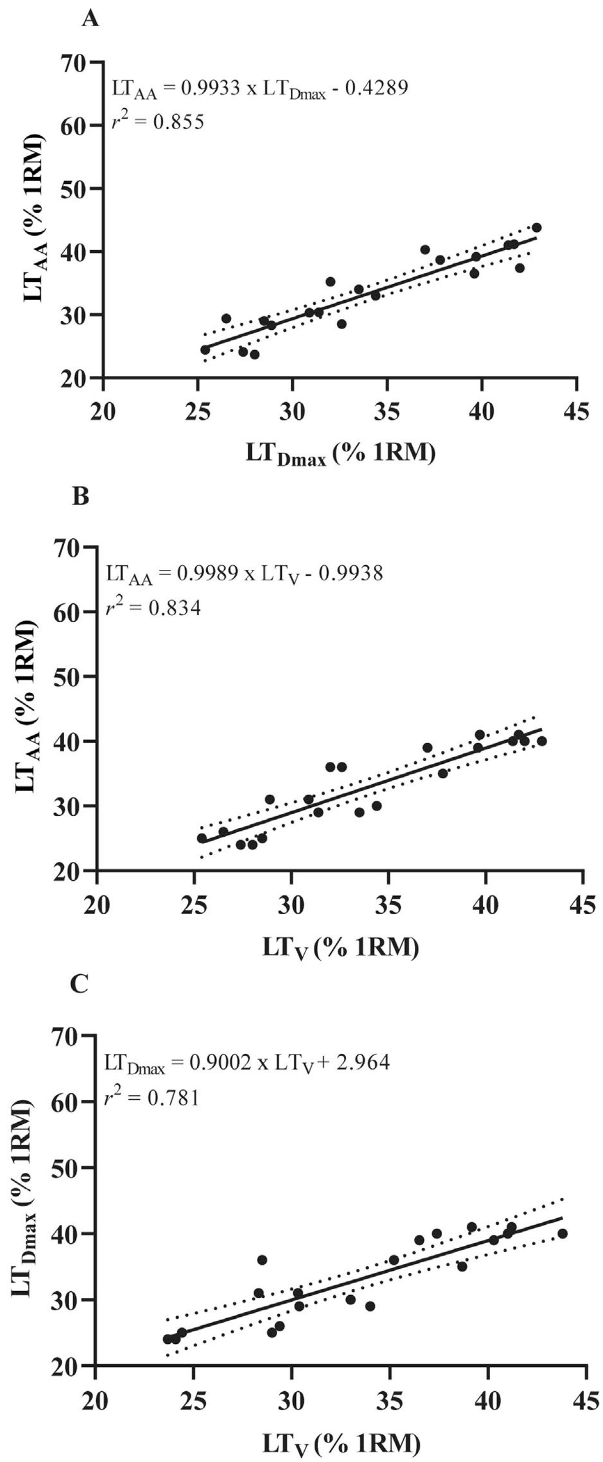

Figure 3 - Linear regression analysis between LT_V and LT_{Dmax} (Figure 3A), LT_V and LT_{AA} (Figure 3B), and LT_{Dmax} and LT_{AA} (Figure 3C).

blood capillaries[29], causing a blockage[30] and reducing the availability of oxygen to the muscle[14], as well as in VO_2 kinetics[31,32]. The muscle hypoxia scenario enhances anaerobic metabolism for ATP production by anaerobic glycolysis. In contrast, under intensities below 30% 1RM some studies showed behavior virtually steady in the BLa kinetics[12,14]. Under steady conditions, the lactate can be recaptured by other muscles, organs, and tissues[26] with the energy demands almost fulfilled by aerobic oxidative metabolism. On the other hand, the progressive increase of the external load induces a sharper production of lactate leading to its greater accumulation in the blood[26]. In parallel, Myers and Ashley[33] reported that the recruitment of different motor units and fiber typologies are associated with the production of the enzyme lactate dehydrogenase. Therefore, during an incremental protocol performed in resistance exercise, greater recruitment of type I (oxidative) fibers initially occurs and gradual exhaustion of aerobic metabolism is followed by greater recruitment of type IIx fibers (glycolytic)[2,11,13,14,19], providing an increase in the contribution of anaerobic metabolism. Recruitment of type IIx motor units stimulates the activity of the enzyme lactate dehydrogenase[34], supporting the production of lactate and causing its exponential increase in higher effort intensities[14]. Thereby, the reduction in oxygen availability caused by a restriction of blood flow in capillaries provides an increase in the participation of the glycolytic pathway, allowing the determination of the transitional moment among different metabolic energy pathways[11,19] and therefore the determination of LT.

Here our data showed that LT was found between 33 and 34% 1RM, regardless of the method used for the determination. Thus, it appears that LT occurs in higher workload percentages in physically active individuals, such as practitioners of resistance training (36.6% 1RM)[27] and long-distance runners (38.3% 1RM)[15] when compared to special populations, such as healthy elderly (30% 1RM)[13,14] and patients with type 2 diabetes (31% 1RM)[16]. In addition, the workload found in our study and by Campos et al.[15], should be considered for the resistance training prescription at LT intensity in long-distance runners to improve cardiorespiratory endurance and muscle strength simultaneously.

Garnacho-Castaño et al.[12] found similarities in the respiratory exchange rate during two different constant-load exercises, half-squat and cycle ergometry in the workload corresponding to the LT. However, the decline in mechanical capacity measured through the countermovement jump (CMJ) observed only during half-squat demonstrated a loss of muscle contractile capacity[35]. Thus, the authors suggested that the performance of resistance exercise in the intensity LT could be an ideal approach for the development of cardiorespiratory endurance and muscle strength, simultaneously[10]. Although some reviews have already highlighted the importance of resistance training for improved performance in long-distance runners[7,8], only one study observed improvements in running performance using a combination of endurance training associated with resistance training at 40% 1RM[9], i.e., close to LT[15]. In this way, the applicability of workloads close to LT in resistance training associated with endurance training has yet to be tested in long-distance runners.

Regarding the comparison among the methods used to determine LT in the leg press 45°, when the algorithm adjustment and visual inspection methods were compared, our results were consistent with the literature[2,19] where we found a very strong correlation (r = 0.91), excellent ICC (0.948), agreement through Bland-Altman plot, and linear regression (r^2 = 0.834). Similarly, Dmax and visual inspection methods demonstrated a strong correlation (r = 0.88), excellent ICC (0.940), agreement through Bland-Altman plot, and linear regression (r^2 = 0.731). The mathematical methods, algorithm adjustment, and Dmax also showed a strong correlation (r = 0.92), excellent ICC (0.959), agreement through Bland-Altman plot, and linear regression (r^2 = 0.855). Some studies in the literature have suggested a steady-state in ventilatory parameters in resistance exercise performed at LT intensity by the algorithm adjustment method[11,12]. Thus, although there is no "gold standard" to evaluate MLSS in resistance exercise, the good correlation and high agreement between the algorithm adjustment and Dmax methods may suggest the reliability of the use of Dmax to determine LT in resistance exercise. However, further studies should be conducted to confirm this assertion as the populations included in the investigations differ in training status, age, and sports activity, making it impossible to use these methods interchangeably[3].

Therefore, mathematical methods for LT determination such as algorithm adjustment and Dmax provide more evaluation accuracy[2,19], favoring LT localization at any workload[2]. On the other hand, despite the reliability found in our study, the visual inspection method is more subjective and requires prior experience of the investigators for the analysis[2,19]. Additionally, the visual inspection method has a limitation as it can only be determined on the workload at which BLa was measured[2].

A limitation of the study corresponds to the fact that we did not verify the BLa steady-state during a constant load protocol of 30-min at LT intensity[11,12]. While there is no "gold standard" to determine MLSS in resistance training, these procedures could further endorse our findings. Another limiting factor that still needs to be studied is the systematization of workload increments. Although the specific literature has shown that LT occurs below 40% 1RM[10-12,15,27] and the protocols are designed to have higher sensitivity below that workload, we suggest that future studies will determine and compare LT during protocols that have different increments in the workloads.

Conclusion

In conclusion, our study demonstrated that the three methods (visual inspection, algorithmic adjustment, and Dmax) evaluated determined LT at similar relative loads (% 1RM). There was a good correlation and high agreement among three evaluated methods suggest their applicability to determine LT during an incremental protocol performed in the leg press 45°. In addition, the workload found in the present study can be used for the resistance training prescription to improve cardiorespiratory endurance and muscle strength in long-distance runners.

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References

1. Faude O, Hecksteden A, Hammes D, Schumacher F, Besenius E, Sperlich B, et al. Reliability of time-to-exhaustion and selected psycho-physiological variables during constant-load cycling at the maximal lactate steady-state. Appl Physiol Nutr Metab. 2016; 42: 142-7.
2. Maté-Muñoz JL, Domínguez R, Lougedo JH, Garnacho-Castaño MV. The lactate and ventilatory thresholds in resistance training. Clin Physiol Funct Imaging. 2017; 37: 518-24.
3. Heuberger JA, Gal P, Stuurman FE, De Muinck Keizer WAS, Mejia Miranda Y, Cohen AF. Repeatability and predictive value of lactate threshold concepts in endurance sports. PLoS One. 2018; 13: e0206846.
4. Browne RAV, Sales MM, Sotero RC, Asano RY, Moraes JFV, Barros JF, et al. Critical velocity estimates lactate minimum velocity in youth runners. Motriz: J. Phys. Ed. 2015; 21: 1-7.
5. Wahl P, Zwingmann L, Manunzio C, Wolf J, Bloch W. Higher accuracy of the lactate minimum test compared to established threshold concepts to determine maximal lactate steady state in running. Int J Sports Med. 2018; 39: 541-8.
6. Zwingmann L, Strütt S, Martin A, Volmary P, Bloch W, Wahl P. Modifications of the Dmax method in comparison to the maximal lactate steady state in young male athletes. Phys Sportsmed. 2019; 47: 174-81.
7. Alcaraz-Ibañez M and Rodríguez-Pérez M. Effects of resistance training on performance in previously trained endurance runners: a systematic review. J Sports Sci. 2018; 36: 613-629.
8. Beattie K, Carson BP, Lyons M, Rossiter A, Kenny I. The effect of strength training on performance indicators in distance runners. J Strength Cond Res. 2017; 31: 9-23.
9. Sedano S, Marín PJ, Cuadrado G, Redondo JC. Concurrent training in elite male runners: the influence of strength versus muscular endurance training on performance outcomes. J Strength Cond Res. 2013; 27: 2433-43.
10. Dominguez R, Maté-Muñoz JL, Serra-Paya N, Garnacho-Castaño MV. Lactate threshold as a measure of aerobic metabolism in resistance exercise. Int J Sports Med. 2018; 39: 163-72.
11. De Sousa N, Magosso R, Pereira G, Souza M, Vieira A, Marine D, Perez S, et al. Acute cardiorespiratory and metabolic responses during resistance exercise in the lactate threshold intensity. Int J Sports Med. 2012; 33: 108-13.
12. Garnacho-Castaño M, Domínguez R and Maté-Muñoz J. Understanding the meaning of lactate threshold in resistance exercises. Int J Sports Med. 2015; 36: 371-7.
13. Simões R, Castello-Simões V, Mendes R, Archiza B, Santos D, Machado H, et al. Lactate and heart rate variability threshold during resistance exercise in the young and elderly. Int J Sports Med. 2013; 34: 991-6.
14. Simões RP, Mendes RG, Castello V, Machado HG, Almeida LB, Baldissera V, et al. Heart-rate variability and blood-lactate threshold interaction during progressive resistance exercise in healthy older men. J Strength Cond Res. 2010; 24: 1313-20.
15. Campos Y, Vianna J, Guimarães M, Souza H, Silva G, Domínguez R, et al. Prediction of the anaerobic threshold in the leg press 45° exercise. Rev Int Med Cienc Act Fís Deporte. 2019; Pendiente de publicación/In press.
16. Moreira SR, Arsa G, Oliveira HB, Lima LC, Campbell CS, Simões HG, et al. Methods to identify the lactate and glucose thresholds during resistance exercise for individuals with type 2 diabetes. J Strength Cond Res. 2008; 22: 1108-15.
17. Orr GW, Green HJ, Hughson RL, Bennett GW. A computer linear regression model to determine ventilatory anaerobic threshold. J Appl Physiol Respir Environ Exerc Physiol. 1982; 52: 1349-52.
18. Cheng B, Kuipers H, Snyder A, Keizer H, Jeukendrup A, Hesselink M. A new approach for the determination of ventilatory and lactate thresholds. Int J Sports Med. 1992; 13: 518-22.
19. De Sousa NMF, Magosso RF, Pereira GB, Leite RD, Arakelian VM, Montagnolli AN, et al. The measurement of lactate threshold in resistance exercise: A comparison of methods. Clin Physiol Funct Imaging. 2011; 31: 376-81.
20. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. Behav Res Methods. 2009; 41: 1149-60.
21. Baechle TR and Earle RW. Essentials of strength training and conditioning. Ed. Human kinetics, 2008.
22. Fell J, Rayfield J, Gulbin J, Gaffney P. Evaluation of the Accusport® lactate analyser. Int J Sports Med. 1998; 19: 199-204.
23. Hinkle DE, Wiersma W and Jurs SG. Applied statistics for the behavioral sciences. Ed. Cengage Learning, 2003.
24. Rosner B. Fundamentals of biostatistics. Ed. Nelson Education, 2015.
25. Bland JM and Altman D. Statistical methods for assessing agreement between two methods of clinical measurement. The lancet. 1986; 327: 307-10.
26. Buitrago S, Wirtz N, Yue Z, Kleinöder H, Mester J. Effects of load and training modes on physiological and metabolic responses in resistance exercise. Eur J Appl Physiol. 2012; 112: 2739-48.
27. Oliveira JC, Baldissera V, Simões HG, Aguiar AP, Azevedo PHSM, Poian PAFO, et al. Identification of the lactate threshold and the blood glucose threshold in resistance exercise. Rev Bras Med Esporte. 2006; 12: 333-8.
28. Hill DW and Butler SD. Haemodynamic responses to weightlifting exercise. Sports Med. 1991; 12: 1-7
29. Petrofsky JS, Phillips CA, Sawka MN, Hanpeter D, Stafford D. Blood flow and metabolism during isometric contractions in cat skeletal muscle. J Appl Physiol Respir Environ Exerc Physiol. 1981; 50: 493-502.

30. Williams MA, Haskell WL, Ades PA, Amsterdam EA, Bittner V, Franklin BA, et al. Resistance exercise in individuals with and without cardiovascular disease: 2007 update: a scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. Circulation. 2007; 116: 572-84.
31. Albesa-Albiol L, Serra-Payá N, Garnacho-Castaño MA, Cano LG, Cobo EP, Maté-Muñoz JL, et al. Ventilatory efficiency during constant-load test at lactate threshold intensity: Endurance versus resistance exercises. PLoS One. 2019; 14: e0216824.
32. Reis VM, Neves EB, Garrido N, Sousa A, Carneiro AL, Baldari C, et al. Oxygen uptake on-kinetics during low-intensity resistance exercise: Effect of exercise mode and load. Int J Environ Res Public Health. 2019; 16: 2524.
33. Myers J and Ashley E. Dangerous curves: a perspective on exercise, lactate, and the anaerobic threshold. Chest. 1997; 111: 787-95.
34. Kohn T, Essén-Gustavsson B, Myburgh K. Specific muscle adaptations in type II fibers after high-intensity interval training of well-trained runners. Scand J Med Sci Sports. 2011; 21: 765-72.
35. Rodacki ALF, Fowler NE, Bennett SJ. Vertical jump coordination: fatigue effects. Vertical jump coordination: fatigue effects. Med Sci Sports Exerc. 2002; 34: 105-16.

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