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ORIGINAL

PREDICTION OF THE ANAEROBIC THRESHOLD IN THE LEG PRESS 45° EXERCISE

PREDICCIÓN DEL UMBRAL ANAERÓBICO EN EL EJERCICIO PRENSA DE PIERNAS A 45°

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ABSTRACT

Objective: Identify the anaerobic threshold (AnT) through blood lactate concentrations (LTDmax) and rating of perceived exertion (RPE) by the Dmax method (RPETDmax), and evaluate the correlation between these methods. **Methods:** Sixteen male long-distance runners participated in the study. Participants performed a gradual incremental test in leg press 45° exercise collecting blood lactate concentrations and perceived exertion. A student's T-test was performed to compare the intensity of exercise in which the LTDmax and RPETDmax were found, and a Pearson test was applied to verify the correlation and intraclass correlation coefficient (ICC). **Results:** No significant difference was found between the LTDmax and RPETDmax (*p*<0.05). In addition, a strong correlation (r=0.73) and high ICC (0.822) were observed between them. **Conclusions:** For the sample studied, it was possible to determine the AnT through the kinetics of RPE.

KEYWORDS: exercise physiology, endurance, aerobic threshold, anaerobic threshold, aerobic-anaerobic transition.

RESUMEN

Objetivos: Identificar el umbral anaeróbico (UAnaer) a través de las concentraciones de lactato sanguíneo ($UA_{NAERDMÁX}$) y mediante la percepción subjetiva del esfuerzo (RPE) por la metodología Dmáx ($U_{RPEDMÁX}$), y evaluar la correlación entre estos métodos. **Métodos:** Dieciséis corredores varones participaron del estudio. Los participantes realizaron un test incremental progresivo en el ejercicio de prensa de piernas a 45° registrando las concentraciones de lactato sanguíneo y RPE. Un test *T-Student* se realizó para comparar la intensidad de ejercicio en la que se encontró el $UA_{NAERDMÁX}$ y $U_{RPEDMÁX}$ y se aplicó un test *Pearson* para verificar la correlación y el coeficiente de correlación intraclase (ICC). **Resultados:** No se encontró diferencia significativa entre los métodos $UA_{NAERDMÁX}$ y $U_{RPEDMÁX}$ (p<0,05). Además, se observó una correlación fuerte (r=0,73) y un ICC alto (0,822) entre ellos. **Conclusiones:** Para la muestra estudiada fue posible determinar el UAnaer a través de la cinética de la RPE.

PALABRAS CLAVE: fisiología del ejercicio, resistencia, umbral aeróbico, umbral anaeróbico, transición aeróbica-anaeróbica

INTRODUCTION

The concept of anaerobic threshold (AnT) has been used in the last fifty years in the clinical and sports contexts (1), where it is considered an important indicator of the yield in cardiorespiratory endurance (2). One of the ways of determining AnT is through the analysis of blood lactate concentrations (3), where the maximal lactate steady state (MLSS), exercise intensity associated with critical power (4) is considered by the sport´s physiologists as reference in the evaluation of the cardiorespiratory endurance performance (1, 5, 6). The MLSS is related to the greater intensity of exercise in which the blood lactate concentrations are stable, existing a balance between the rate of production and elimination of lactate (7), which allows maintaining the effort during a long period of time before the fatigue appears (8). The main disadvantage of the MLSS detection is that determination requires several evaluation sessions in which the athlete should go to the laboratory. (9). Thus, athletes must perform successive 30-minute tests at constant intensity with loads located between lactate threshold (LT) and peak of oxygen uptake (VO_{2peak}), identifying MLSS as the highest exercise intensity where blood lactate concentrations do not increase more than 1 $mmol \cdot l^{-1}$ by 10 to 30 minutes (10). In order to reduce the number of sessions, as well as the complexity in determining MLSS, it has been proposed easier protocols for estimate AnT across a gradual incremental test (11).

Traditionally, LT has been determined in cyclical exercise modalities through incremental tests (6, 7, 11). However, some research has begun to determine this parameter in exercises used for resistance training (3, 12, 13). In this last modality of exercise, when relativizing this intensity as a percentage of a maximal repetition (% 1RM) during incremental tests in resistance exercises (leg press 45°), LT was determined at intensities around to 30% in elderly (14, 15), 31% in patients with type 2 diabetes (16) and between 32.3 and 36.6% in subjects with experience in resistance training (17, 18). Recently, some studies has proposed that resistance training performed in the LT intensity can be an effective training to improve in both, strength and cardiorespiratory endurance parameters (19); being adequate for the periodization of resistance training in individuals who seek to improve their health and quality of life, as well as in athletes who seek to improve their athletic performance (20). However, to date, no research has determined the use of LT in exercises used for resistance training in cardiorespiratory endurance athletes, making it difficult to programming this type of training in this population.

As the determination of blood lactate is an invasive and expensive test, some investigations have used the monitoring of the rating perceived exertion (RPE) with the aim of predicting LT through incremental tests in cyclic exercises used for the development of cardiorespiratory endurance (21-23), as in the exercises used for the muscular strength development (24). In this context, RPE would become a more economical alternative to blood lactate (23), reducing the costs and complexity of the determination (24, 25). In addition, the OMNI scale has already been used in physical exercises for resistance training, where it has proved to be a valid tool in predicting energy expenditure during exercise (26).

Borg (27) proposed RPE as a valid method for the determination of AnT, since it represents the integration of central and peripheral signals of several systems, being an indicator of heart rate, blood lactate or ventilation during exercise (28). Thus, some investigations found strong correlations between AnT, measured by blood lactate concentrations (21-24) and by RPE (RPET). Mainly, when LT and RPET were determined by the Dmax method proposed by Cheng et al. (29), indicating that the RPET could be a good predictor of the AnT (21, 22, 24), could be a non-invasive, low-cost and complex instrument to identify the AnT in long-distance runners during the execution of exercises used for resistance training.

OBJECTIVE

The objectives of the present study were to identify AnT through blood lactate concentrations using the Dmax methodology (LTDmax) and through the RPE using the Dmax (RPETDmax) methodology. The second objective of the research was to evaluate the concordance and correlation between LTDmax and RPETDmax during an incremental test in leg press 45º exercise in trained long-distance runners. Our two research hypotheses are: i) it is possible to determine LTDmax and RPETDmax in a gradual incremental test in leg press 45° exercise in long-distance runners; ii) there are a high concordance and correlation between both forms of determination and RPE OMNI-RES scale.

MATERIAL AND METHOD

Subjects

Sixteen amateur male long-distance runners (age: 27.28 ± 2.54 years; relative body fat: 9.98 ± 3.52 %; height: 1.78 ± 0.05 m; body mass: 74.22 ± 5.58 kg) with experience in competitions of 5,000 and 10,000 meters (5,000 m: 21 minutes and 28.7 seconds ± 1 minute and 24 seconds; training experience: 3.26 ± 0.89 years and with their marks approximately 60% of the Brazilian record of 5,000 m in road running) participated voluntarily in the present study. The inclusion criteria for participation in the study were as follows: a) legal age; b) does not have any bone, muscular and cardiovascular pathology; c) participate regularly in running road of 5,000 and 10,000 m (at least 6 competitions per year); d) have experience in resistance training and, specifically, with leg press 45° exercise; (e) have not taken any nutritional supplement or medicinal product within 3 months prior to commencement of the investigation; f) not be considered an elite athlete. Before conducting the research, according to the Declaration of Helsinki, the study was approved by the local ethics committee (CAAE: 53675416.3.0000.5148), all volunteers signed a consent form after attending an information session in which all questions regarding the research were resolved.

Experimental design

The subjects performed 6 laboratory sessions in the same time interval (± 0.5 hours) with the same environmental conditions (20°C and 60% relative humidity) separated from each other by a period of 48 hours. In the 1st session, the participants performed the anthropometric measurements and were informed of the procedures that would be performed in the subsequent sessions, and then signed the informed consent. In the 2nd and 3rd sessions, the subjects performed a 1RM evaluation test in the leg press 45º exercise. In the 4th session, the subjects performed a familiarization session with the OMNI-RES scale in the leg press 45° exercise. In the 5th and 6th sessions, the subjects performed a progressive incremental test in the 45° leg press exercise collecting the blood lactate or RPE concentrations at the end of each stage with different workloads, and the sequence of the two sessions was randomized in all volunteers.

Anthropometric evaluation

To perform the characterization of the sample, an anthropometric data collection was performed. Thus, height and body mass were evaluated by means of a stadiometer (110 FF, Welmy®, Santa Bárbara d'Oeste, Brazil) and the body fat percentage was estimated by electrical bioimpedance (Amount BIA-II, RJL Systems®, Clinton Township, USA) using four-electrode type electrodes (Bio Tetronic, Sanny®, São Bernardo do Campo, Brazil).

1RM test

The 1RM determination was performed following the guidelines of the National Strength and Conditioning Association (30). In this way, the test started with the first set being carried out from an estimated load around 50% of 1RM based on the load conventionally used by participants to perform their training between 8 and 10 maximal repetitions in the leg press 45° exercise. After a passive recovery of 2 to 4 minutes or until the subjects had a complete perception of recovery, a progressive increase of 10% was performed in relation to the previous workload. When the subjects reached failure, the load was reduced by 5%. The 1RM was established as the highest load that the subjects moved while maintaining a correct execution technique.

Familiarization with OMNI-RES scale

During the familiarization process, the OMNI-RES scale was presented to participants being simultaneously explained that it was a scale that used visual and numerical descriptors to classify the perception of effort during the performance of resistance training. Then, according to the recommendations by Robertson et al., (31), participants read a definition as a whole. The scale was used through a visual-cognitive link (32), being the main objective that the subject established a cognitive relationship between the intensity of the effort with the visual and numerical descriptors of the scale. The subjects were instructed to memorize and experiment from the smallest to the greatest effort while lifting the charges to help establish a visual-cognitive connection. In addition, the subjects were instructed to indicate the perceived effort on the scale and not to respond verbally to the RPE when requested by the researchers.

Progressive incremental test in the leg press 45° exercise

During the gradual incremental test in leg press 45º exercise (Physicus®, Auriflama, Brasil), subjects performed 1-minute sets of work in which performed 20 repetitions at a rhythm of 20 repetitions per minute (1 second during the concentric phase and 2 seconds during the eccentric phase) externally controlled through a digital metronome (DM90, Seiko®, Tokyo, Japan) (33, 34). The loads used during the test were 10, 20, 25, 30, 35 and 40% of 1 RM. From 40% 1RM, the load increments were 10% 1RM (50%, 60% of 1RM...). The test was finalized when the subjects were unable to perform 20 repetitions during the working set at the rhythm imposed. (33, 34). The recovery period between each work stage was 2 minutes, in which blood lactate and RPE were collected. Throughout the session, the subjects remained seated in the machine with the trunk in a horizontal inclination of 45º and knee flexion in 90º (15). During the exercise, knees and hips were extended and returned to the initial position after flexion (15). The movement was controlled through a digital goniometer (GN360, Miotec® Equipamentos Biomédicos Ltda, Porto Alegre, Brasil).

Measurement of blood lactate

Immediately, after the end of each stage in the leg press 45° exercise, the 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 a puncture in the earlobe. Next, the first drop of blood was dismissed, and then, 25µL of capillary blood was collected. For the analysis of blood lactate, a portable lactate analyzer was used (Accusport, Boehringer Mannheim - Roche®, Hawthorne, USA), previously proven valid and reliable (35). Before the start of each evaluation session, the lactate analyzer was calibrated with different standard solutions of known lactate concentrations (2, 4, 8, and 10 $mmol \cdot l^{-1}$).

Measurement rating of perceived exertion

For the measurement of RPE during the gradual incremental test, OMNI-RES scale was used (31), with the corresponding visual and numerical descriptors ranging from "extremely easy" (zero) to "extremely difficult" (10). About 30sec after the end of each stage during the incremental protocol, the participants pointed out their classification based on the OMNI-RES scale. Throughout the test, subjects had the scale in sight, and during the final repetitions of each set participants were instructed to "think about your perceived exertion during exercise".

Determination of the LTDmax and RPETDmax by Dmax method

The Dmax method (29) consisted of the application of a 2nd-order polynomial adjustment in the kinetics of lactate concentrations (LTDmax) and RPE (RPETDmax) as a function of effort intensity, followed by a linear fit, an equation being derived for each adjustment. Subsequently, the "x" of the equations was replaced by the values of the absolute intensities of each stage of the applied incremental protocol. The values obtained were subtracted by the equation (linear – polynomial), and the Dmax being considered as the largest observed difference (Figure 1 and Figure 2).

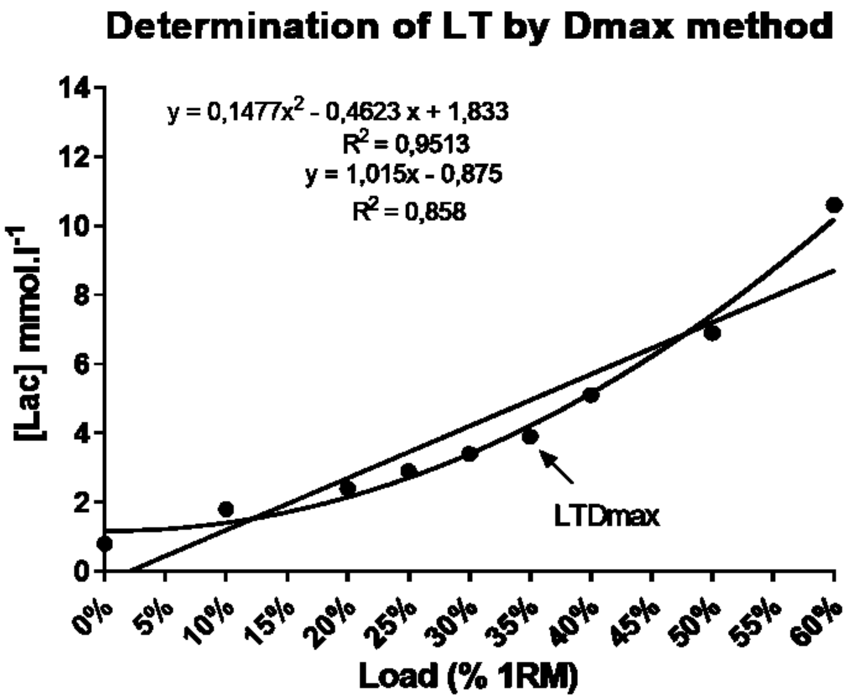

Figure 1: Determination of LT by Dmax method in the gradual incremental test performed in leg press 45° exercise

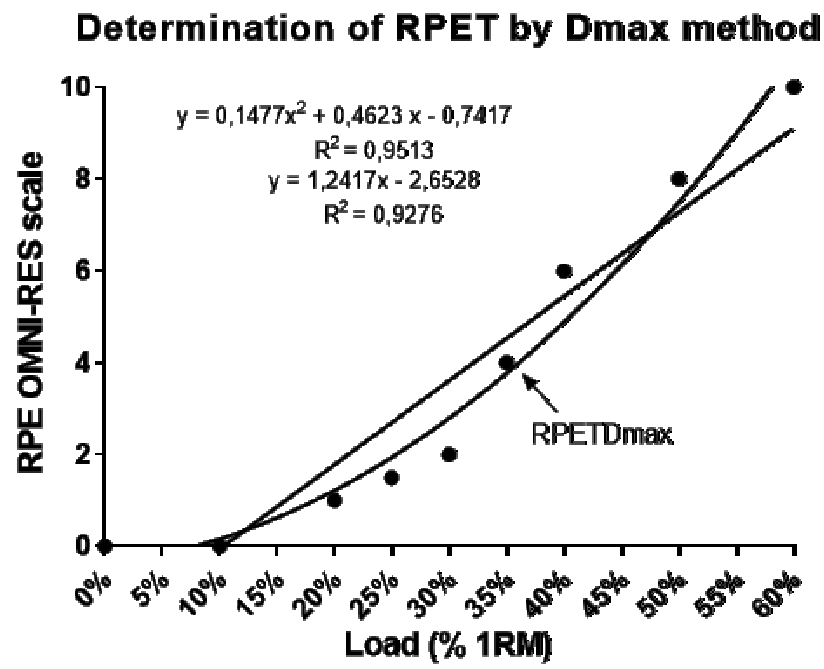

Figure 2. Determination of RPET by Dmax method in the gradual incremental test performed in leg press 45° exercise

Statistical analysis

To verify the normality and homogeneity of the variances Shapiro Wilk and Levene´s tests were adopted. Confirmed the assumptions of normality and homogeneity of variances, a T-test for dependent samples was used to compare the LTDmax and RPETDmax in the gradual incremental test performed in leg press 45° exercise. Effect size (ES) was calculated according to Cohen's (d) test, from the following formula: d = (group 1 mean - group 2 mean)/standard deviation. To verify the correlation between the LTDmax and RPETDmax methods, a Pearson test was applied. The correlation interpretation followed the classification criteria proposed by Hinkle et al. (36): 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. To verify the concordance index between LTDmax and RPETDmax, the intraclass correlation coefficient (ICC) was calculated. Additionally, for the analysis of agreement between LTDmax and RPETDmax, an analysis of Bland-Altman plot was performed (37). The value of the assumed statistical significance was $p<0.05$. For the statistical analysis, SPSS software (20.0, IBM, Armonk, USA) was used.

RESULTS

ICC for the 1RM test-retest was 0.962 (excellent). When analyzing the relative load (% 1RM) between LTDmax and RPEDmax, no statistically significant differences were observed ($p=0.074$, ES=0.035: small), while a strong correlation was observed ($r=0.73$) and a high ICC (0.822) (see Table 1).

Table 1. Data corresponding to the comparison between LTDmax and RPETDmax during the gradual incremental test in leg press 45º exercise

Relative Load (% 1RM)	Relative Load (% 1RM)	Significance (*p*)	Correlation (*r*)	Correlation significance (*p*)	ICC
LTDmax	RPETDmax				
38.3 ± 2,9	37.3 ± 2,8	*p*= 0.074	r= 0.73*	*p*= 0.001*	0.822

*$p<0.05$ for correlation between the LTDmax and RPETDmax

Regarding the lactate concentrations in LTDmax, these were 5.05 ± 1.26 mmol·l-1, while the RPE values in RPETDmax were 5.37 ± 1.36 points. The visual analysis of Bland-Altman plot (Figure 3), was observed agreement between LTDmax and RPETDmax during the gradual incremental test in leg press 45° exercise, with 100% of the data within the confidence interval ± 1.96.

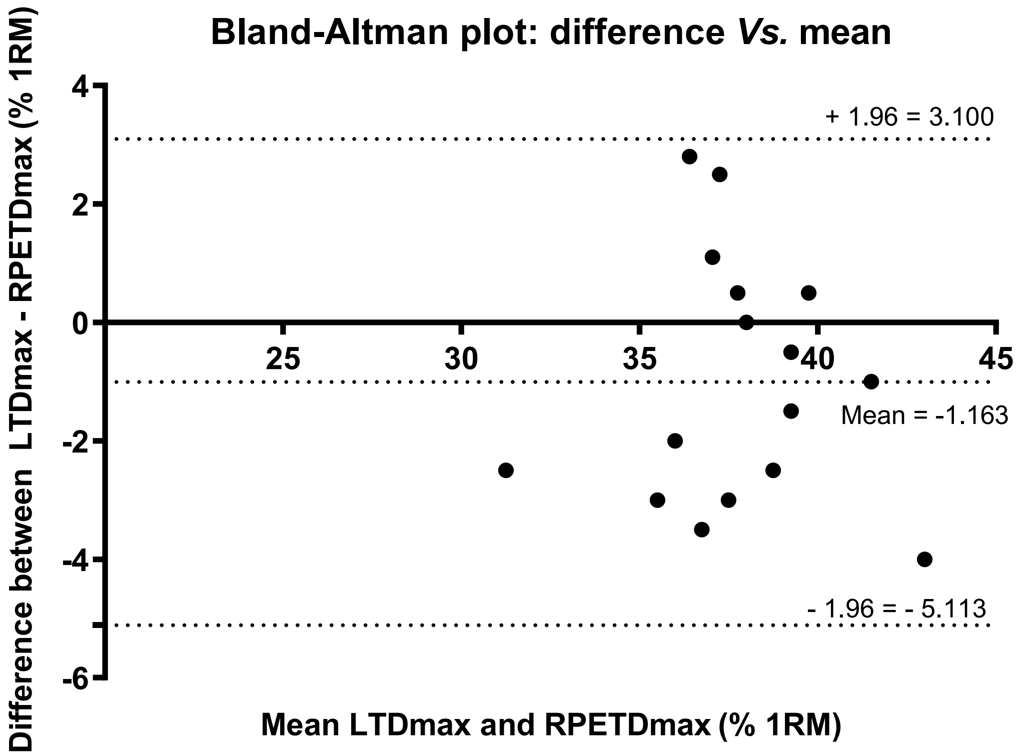

Figure 3. Agreement between LTDmax and RPETDmax as % 1RM

Discussion

The objectives of our research were to identify the AnT through the LTDmax and RPETDmax during the gradual incremental test in the leg press 45° exercise, as well as to analyze the correlation and agreement between both parameters. Our initial hypotheses were confirmed, being possible to determine the AnT through the LTDmax and RPETDmax, being found a strong correlation and agreement between both methods of determination.

The mechanisms that allow the determination of LTDmax through blood lactate concentrations can be explained by hemodynamic and physiological mechanisms (33). In this sense, several investigations have reported an occlusion of the blood capillaries of the active musculature (15) in exercise intensities greater than 30% 1RM (14-17, 33, 34). The occlusion causes a blockage of the capillaries (38) significantly reducing blood flow (15) and diminishing the bioavailability of oxygen for the active musculature (15), inducing an increase in the glycolytic contribution to energy metabolism (33, 34). The increase in exercise intensity causes a greater occlusion and, therefore, a greater glycolytic contribution (increasing the recruitment of type II glycolytic motor units to the detriment of type I oxidative motor units) (15), stimulates the activity of the lactate dehydrogenase enzyme (39) leading to an exponential increase in blood lactate concentrations as intensity of exercise is increased (15). That way, a reduction of the bioavailability of oxygen as a consequence of vascular occlusion, leads to the recruitment of motor units with a greater glycolytic activity that allows the AnT determination (33, 34). Recently, in a systematic review, it was concluded that AnT can be identified in exercises used for resistance training at intensities ranging between 27 and 36% 1RM

(20), however, in the present investigation, it has been found that the LTDmax occurred at a slightly higher intensity (38.3% de 1RM). A possible explanation of the highest values found in our research may originate from the subjects who composed the sample. This way, Messonnier et al., (40) observed that cardiorespiratory endurance athletes have a greater ability to remove lactate during exercise, therefore, this increased capacity for lactate clearance could affect blood lactate kinetics during progressive incremental tests in exercises used for resistance training, resulting in the LTDmax occurrence at higher intensities in cardiorespiratory endurance runners.

The popularization of RPE scales for the AnT determination aroused the scientific community's interest in evaluate and/or validate through other physiological reference parameters, such as blood lactate concentrations (21-24) and ventilation (41). During the effort, the increase in RPE is related to changes in homeostasis, among which metabolic acidosis, increased oxygen uptake or heart rate (28, 42, 43). Thus, RPE during exercise is mediated by metabolic and peripheral changes occurring during muscle contraction that would be perceived by afferent nerve endings III and IV, transmitting this information directly to the central nervous system (CNS) (44), stimulating the sensory areas of the brain. Therefore, RPE during exercise can be influenced by sensory feedback (45) developing the series of psychophysiological sensations responsible for the modulation of RPE during exercise. Among the metabolic alterations reported in the literature, which supposedly could act as one of the CNS signals, and thus influence the RPE response, we find the lactate concentrations (46). In this line, in exercises used for the development of cardiorespiratory endurance, a strong correlation was found between LTDmax and RPETDmax (21-23). Thus, in an investigation similar to ours, Arsa et al. (42) evaluating resistance training practitioners subjects and found agreement and a moderate correlation (r = 0.63) between LTDmax and RPETDmax during a progressive incremental test in the horizontal leg press. Unlike our research, in the previous investigation, Arsa et al. (24) used a Borg scale (6-20). However, our research is the first to use the OMNI-RES scale, specifically validated for resistance training (31), in the LTDmax determination in exercises used for this type of training. That way, both the strong correlation (r= 0.73, *p*= 0.074) and agreement (ICC = 0.82) and the Bland-Altman plot (Figure 3) show a strong association between LTDmax and RPETDmax in the identification of AnT while performing exercises used for resistance training. Therefore, our results are in line with other investigations that observed a strong correlation and concordance between LTDmax and RPETDmax in exercises used for cardiorespiratory endurance training, such as treadmill running (21, 23) and cycle ergometer (22).

Despite some differences in the mechanisms responsible for the modulation of RPE during exercise (47), which even make it possible to use it for determination of the AnT, we believe that it is an economic tool with higher practical applicability for the monitoring and prescription of the effort intensities (24, 25), in relation to the use of blood lactate concentrations (21-24) and the ventilatory parameters (41), which require more sophisticated equipment (23) making it difficult to use during training and competition environment (41). Additionally, at the practical level, the performance of resistance training programs in RPETDmax intensity may be appropriate for cardiorespiratory endurance athletes, since it has been proven that the training performed in the LTDmax intensity is capable of producing cardiovascular and mechanical responses, which proposes it as an excellent opportunity to simultaneously develop cardiorespiratory endurance and muscular strength (19, 20).

CONCLUSION

The results show that for the studied sample it was possible to determine the AnT through the RPE kinetics during an incremental test in an exercise used for resistance training. That way, our results showed agreement and strong correlation between LTDmax and RPETDmax determination methods. Mainly, due to the fact that the kinetics of the OMNI-RES scale is very similar to that of the blood lactate concentrations during the progressive test in the leg press 45° exercise. However, we recommend additional studies to verify if the OMNI-RES scale can be recommended for the evaluation and prescription of exercise intensity in resistance training for other populations.

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