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Correlation between Blood Lactate and the Rate of Perceived Exertion in Different Resistance Exercises

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Abstract

Aim: *Analyze the production of blood lactate [BL] and the rate of perceived exertion [RPE] after the following exercises: bench press, half-squat, lat pull-down and triceps pushdown.*

Method: *The sample was selected by convenience. Seven male volunteers (mean age: 26.5 ± 5.42 years old; body height: 1.77 ± 0.07 m; body mass: 80.09 ± 11.4 kg and body fat: 11.23 ± 4.6%) participated in the study. To be included in the sample, volunteers were required to have at least one year of continuous experience in resistance exercise training of at least three times per week and no history of anabolic steroid use.*

Results: *There was no difference in BL production (F {3; 3.692} = 0.689; p = 0.58) or peak BL time (F {3; 222.527} = 1.400; p = 0.27) among the exercises studied. There was also no significant difference between the BL peak and the exercise performance time (F {3; 2.722} = 1758; p = 0.06).*

Conclusions: *Considering the discrepancies found among these results and others already reported, caution should be taken when applying the OMNI-RES scale as a method for adjusting resistance exercise intensity. Further studies are recommended to determine the influence of different variables related to resistance exercise [RE] on the RPE.*

Keywords: *resistance training, lactate, omni-res scale.*

Introduction

Resistance exercise [RE] is a prescribed activity that aims to develop muscle strength, resistance, power and hypertrophy[1]. At the end of the 1990s, resistance training was adopted to prevent and treat degenerative chronic diseases[2,3]. Despite its broad use, there are gaps in knowledge regarding the physiological responses and psychological adaptations related to resistance training[4,5]. Within this context, researchers evaluated the concentration of blood lactate [BL] as a variable to determine the intensity of physical effort and to estimate the energetic demand during resistance training, which are together known as the Rate of Perceived Exertion [RPE][6,7].

Nevertheless, there are inconsistencies in the literature referring to the applicability of the RPE as a method to determine RE intensity. This is in spite of the fact that the RPE has been significantly associated with the number of repetitions, intensity, load and duration of the recovery interval[8]. Moreover, previous studies have indicated a significant correlation between BL and the RPE[9]. Therefore, the OMNI-RES scale has been used to determine the intensity of RE[10]. Given these studies, the question arises as to the extent of association between BL and the OMNI-RES scale and what is the concentration of lactate in a resistance training set performed at an intensity of 80% of 1RM.

Some studies point to the importance of perceived exertion as a valid tool for prescription of exercise intensity when the purpose is to use lactate concentration as an intensity marker[11,12]. In this sense, using the concentration of lactate as a physiological tool associated with the perceived exertion scale is necessary to support your application with resistance training.

However, the evidence showed that the size of muscle mass involved and the type of motor request [mono versus multi-joints] have an effect on physiological responses as well as on the RPE[8,13,14]. Therefore, the present study analyzed the responses of blood lactate and the RPE after the following exercises: bench press, squat, lat pull-down and triceps pushdown. The hypothesis was that the squat exercise would promote greater BL production and the RPE when compared with the other exercises.

Methods

The sample was selected by convenience. Seven male volunteers (mean age: 26.5 ± 5.42 years; body height: 1.77 ± 0.07 m; body mass: 80.09 ± 11.4 kg and body fat: 11.23 ± 4.6%) participated in this study. To be included in the sample, volunteers were required to have at least one year of continuous experience in RE with a training frequency of at least three times per week and no history of anabolic steroid use. All volunteers signed a written consent form after being informed about the experimental protocol and the possible risks associated with the study. Participants were free to withdraw from the experiment at any time of the study. The protocol was approved by the Ethics Committe of the University of Trás-os-Montes and Alto Douro (EC-UTAD) in accordance with the Resolution 196/96 of the National Health Council.

After enrolling in the study, volunteers were submitted to anthropometric measurements to estimate their body composition. The Skinfold Thickness Method was used, and the following measures for the skinfolds were obtained: subscapular, triceps, chest, media underarm, supra-iliac, abdominal and thigh, using a Lange® skinfold caliper. These measures were taken in a rotation system on the right side of the body and by a single experienced evaluator. The body density and overall body fat were calculated by the Jackson and Pollock[15] and Siri[16] equations, respectively. At the end of the anthropometric measurements, volunteers were instructed not to perform strenuous physical activities and not to drink alcoholic beverages 24 h before the tests and RE sessions. They were also guided to have a light meal at least 2 h before and not to drink caffeinated drinks 3 h before the session.

Experimental Protocol

The investigation protocol followed these steps:

Muscle strength was measured using the dynamic 1RM test across the following exercises: bench press, half free weight squats, lat pull-down, and triceps pushdown. The tests were performed during one day in a randomized manner, respecting the recovery interval of 5 to 10 minutes between exercises.

The following procedures were used to perform the 1RM tests according to a previous study conducted by Kraemer et al.[4]: 1) general activation with five to ten repetitions with a load between 40 and 60% of the perceived maximum, followed by 1 min of stretching; 2) three to five repetitions with a load between 60 and 80% of the maximum load, followed by a 2 min rest period; and 3) one attempt at the maximum load. After the participants succeeded or failed at the maximum load, they were allowed to rest for 5 min, and the load was increased or decreased for the next attempt. The maximum load (kg) was designated as the load with which participants were able to perform a single repetition out of five attempts. Participants with greater differences than 5% were required to appear at the test site again to perform additional tests, and the differences between test sessions were calculated. Between-test exercises that might interfere with the results during the 48 h period were not allowed. A professional with experience in resistance training accompanied the participants throughout testing.

To assure that all volunteers performed the exercises at the same rate (40 bpm; 20 repetitions per minute), namely, two seconds in the eccentric phase and one second in the concentric phase, an electronic metronome was used [Qwick Time™, China]. The analysis of the blood lactate concentration was carried out immediately after each set of exercises and 25 µl of blood from one of the left hand fingertips of the distal phalanx were collected to determine BL concentration. An Accutrend analyzer [RECHO®, US] was used to estimate BL considering that its usefulness as a reference instrument [$R^2 = 0.991$, SEE = 0.39 Mm] had been previously described in a study by Baldari et al.[17].

The lactate collection was repeated every 90 s until a maximum value was recorded. Before each session, the electronic metronome was calibrated with the chip provided by the manufacturer. This procedure was also carried out after each set. Before and during each exercise, the RPE was obtained using the OMNI-RES scale from 0 to 10[18].

Data Analysis

Shapiro-Wilk and Mauchly tests were conducted to analyze the data obtained. ANOVA repeated measures analysis was used to compare blood lactate concentrations at 90 s recovery intervals after each exercise set. Only parametric data were employed. The Bonferroni Post Hoc test was used to identify significant differences. The Pearson correlational coefficients were applied to determine the association level between blood lactate concentration and the OMNI-RES scale. Data were analyzed using SPSS statistical software 20.0, and the level of significance was set at 0.05.

Results

The mean values of blood lactate, recovery time, OMINI-RES scale and maximum repetitions are presented in Figure 1. Blood lactate concentrations (F{3; 3.692} = 0.689; p = 0.58) and peak blood lactate time (F{3; 222.527} = 1.400; p = 0.27) were not significantly different among the four exercises. There was also no significant difference between the peak of blood lactate time and the exercise performance time (F{3; 2.722} = 1758; p = 0.06).

	Bench press	Half-squat	Lat pull-down	Triceps Pushdown
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
1RM (kg)	90.71 ± 23.53	105.0 ± 23.63	92.86 ± 13.80	44.50 ± 12.37
Weight load 80% (kg)	70.42 ± 17.67	88.27 ± 20.35	74.67 ± 11.05	36.54 ± 9.92
Repetitions	8.0 ± 0.5	11.0 ± 4.18	10.0 ± 1.95	11.0 ± 5.19
time max La (s)	67.50 ± 13.89	82.50 ± 13.89	72.86 ± 16.04	72.86 ± 16.04
max La (mMol)	5.54 ± 1.62	5.84 ± 1.92	6.90 ± 1.94	6.20 ± 2.21
OMNI-RES	7.0 ± 0.5	7.0 ± 1.25	7.0 ± 0.90	7.0 ± 0.95

Figure 1. *Mean and standard deviation at the maximal blood lactate concentration (max[La]), time of occurrence maximal blood lactate concentration (time max[La]), number of maximum repetitions and rate of perceived exertion according to the OMNI-RES scale in young males submitted to four resistance exercises.*

The results obtained for blood lactate concentrations during the recovery periods are presented in Figure 2 a-d for the following exercises: bench press, half-squat, lat pull-down and triceps pushdown. The results indicated a significant difference in blood lactate concentration during the recovery period for the exercises involving the upper limbs. The bench press exercise revealed differences among all blood collection intervals (Figure 2 a,b,c), in which the blood lactate concentration at the first measurement was higher than those at measurements 2 and 3 (Wilk's Lambda F {2; 5.529} = 5.000; p = 0.04).

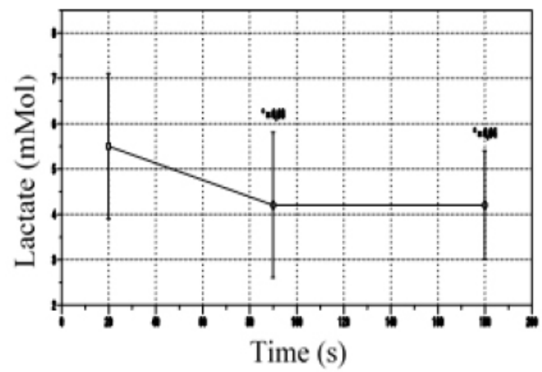

Figure a. *lactate concentration curve for bench press exercise at 80% IRM in healthy males.*

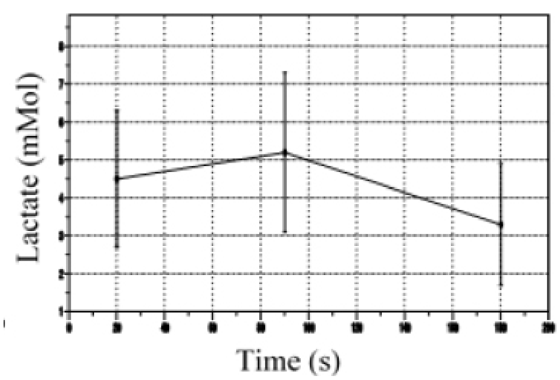

Figure b. *lactate concentration curve for the squate exercise at 80% IRM in healthy males*

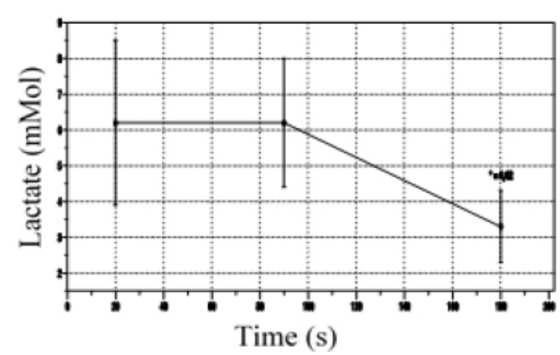

Figure c. *lactate concentration curve for the lat pull down exercise at 80% IRM in healthy males*

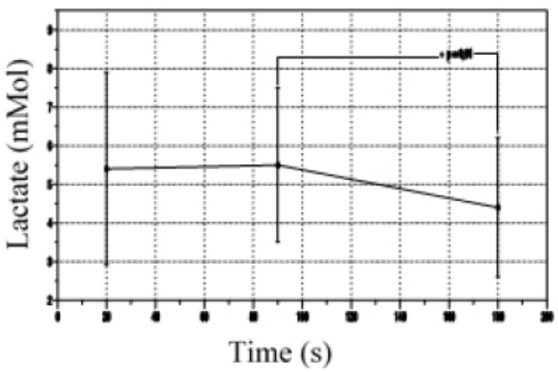

Figure d. *lactate concentration curve for the triceps pushdown exercise at 80% IRM in healthy males*

Figure 2. *a,b,c e d - Results obtained for blood lactate concentrations during the recovery periods.*

A similar pattern was observed for the lat pull-down and triceps pushdown exercises; for the former, the significant difference (Wilk's Lambda F {2; 7.258} = 5.000; *p* = 0.02) was observed after the third blood collection. These results indicate that a longer recovery time is required when blood lactate drops because the curve described in Figure 2c is stable between the first and second blood concentration measurements. When the blood lactate was analyzed for the triceps pushdown, the significant difference (Wilk's Lambda was F {2; 12.040} = 5.000; *p* = 0.01) between the blood lactate concentrations at the second and third collections was observed (Figure 2d). With regard to the squat exercise, no significant differences were observed for blood lactate concentrations at the three collection time points (Wilk's Lambda F{2; 4.273} = 5.000; *p* = 0.08).

There were no significant differences among the four exercises regarding blood lactate peak concentration or time. The comparison between the OMINI-RES scale values and blood lactate concentrations provided no significant differences as shown in Figure 3.

	Immediately after		90 s		180 s	
	r	*p*	r	*p*	r	*p*
Bench press	-0.26	0.58	-0.63	0.13	-0.70	0.08
Half-squat	-0.38	0.41	-0.37	0.42	-0.30	0.52
Pull-down	-0.27	0.56	-0.13	0.78	0.55	0.20
Triceps pushdown	0.09	0.98	0.38	0.40	0.20	0.64

Figure 3. *Values obtained of the association level between OMNI-RES and blood lactate for the exercises Immediately after, 90 s and 180 s.*

Discussion

In this study, an important aspect found was the relationship between perceived exertion and blood lactate concentration during resistance exercises. In this sense, observing the protocol used in the study by Kraemer et al.[4], some care must be taken, including: clarification regarding familiarization with the OMNI-RES scale, number of repetitions performed at intensities proposed, recovery interval and evaluation of the maximum load. Thus, the use of the scale of perceived exertion seems to be a reliable method for measuring stress in different resistance exercises, which it is important for the proper control of training variables involved in the study. Another practical application of the study results from the relationship between blood lactate concentration and perceived exertion that may be used as a control method of training intensity in resistance exercises.

In the present study, participants' responses regarding blood lactate and the RPE as measured through the OMNI-RES scale were analyzed after one set of resistance exercises at 80% of 1RM. The results suggest that the body mass involved and the type of muscle exercise performed did not influence blood lactate concentration and the RPE during resistance exercise.

These findings are related to previous studies, which present evidence that multi-joint and higher intensity exercises promote higher lactate concentrations as well as greater tissue damage that leads to hypertrophy[4,9,19]. Izquierdo et al.[14] noted blood lactate as a factor related to motor deficit as the surface electromyography signal presented alterations after a short training period. This fact was not observed in the present study because the subjects performed the number of repetitions required for each exercise without displaying motor deficits. The blood lactate increase is also related to tissue damage that leads to hypertrophy[20].

Furthermore, Abernethy and Wehr[21] determined a greater influence of 5RM and 15RM over the lactate concentration during resistance exercises. The authors highlighted that the intensity for the 5RM set was higher than that for the 15RM set. The number of repetitions performed by volunteers during the present study was not higher than 15RM (Table 1), which can be described as a determining factor for the high blood lactate levels after the exercises. Within this context, Kraemer et al.[4] described increases in blood lactate with significant drops after the 4th and 5th recovery minutes, which is in accordance with data obtained by Abernethy and Wehr[21]. These results are similar to those observed in the present study, as we found blood lactate drops after the 3th min of recovery.

However, Wirtz et al.[9] presented different results when compared with those obtained in this study. The authors observed a significant increase in lactate concentration within the first recovery minute after the 3rd set of resistance exercises at 30% of 1RM. What may partially explain the differences observed among the Wirtz et al.[9], Kraemer et al.[4], Abernethy and Wehr's[21] studies and this one could be the number of sets performed. This fact would be responsible for producing bigger mechanical constriction to the blood flow, which would lead to a lower concentration gradient in lactate during the exercise and, as a result, increased blood lactate concentration within the first recovery minute. It is important to note that in the Wirtz et al.[9] study, blood lactate concentration dropped after the 6th minute, whereas our results show that the blood lactate reduction occurs 2 minutes after recovery.

The observations of Wirtz et al. [9] diverge from those reported in the literature in which lactate concentration drops within the first minute after the exercise. On the other hand, this report supports the results presented for the Kaatsu method, which leads to hypoxia through vein and artery occlusion by producing increases in blood lactate concentration in resistance exercise sessions with an intensity of 30 and 40% of 1RM. This increase of blood lactate concentration also causes a higher rate of perceived exertion due to the discomfort generated by occlusion of the section[22,23]. It is important to emphasize that the intensity of 30% of 1RM is higher than the lactate threshold for resistance exercises[24,25] resulting in an energetic demand through the glycolytic pathway[26,27]. Moreover, the number of repetitions and performance in the eccentric and concentric phases may be considered as determining factors in perceived exertion. Kulig et al.[28] analyzed the answer for muscle pain for the triceps pushdown submitted to an intensity of 60% of 1RM and reported that 58% of subjects presented a higher pain perception when the exercise was performed at a faster than slower pace.

In the present study, the exercises were conducted at a 2 s pace in the eccentric phase and a 1 s pace in the concentric phase. Nevertheless, the RPE obtained using the OMNI-RES scale did not present a significant association with the lactate concentrations, as observed in the Robertson et al.[29] study. The results obtained can be explained by the number of sets performed. In the Robertson et al.[29] study, subjects executed 3 sets, and in the present study, they only performed 1 set, which suggests that caution should be exercised when interpreting the results. However, the results presented are in line with those of previous studies in which low levels of association between the OMNI-RES scales and resistance exercise were also found. What can be emphasized for both scales is the performance order of the exercises[30].

RE studies show that the acute RPE systematically increases along with the percentage of 1 repetition maximum (1RM) lifted when exercise is terminated at a predetermined number of repetitions (reps)[18,31,32]. Furthermore, in a study comparing a session RPE across 3 different workouts involving 5 exercises (1 set each) at 50% (15 reps), 70% (10 reps), and 90% (5 reps) of 1-RM, Day et al.[33] found a session RPE to be reliable for quantifying intensity during RE and concluded that session RPE values increased concurrently with the percentage of 1RM. Additionally, it has been documented that a significant relationship occurs between the RPE and BL during resistance training with intensity ranging from 60 to 70% of 1RM and high volume (5-6 sets of 10-15 reps) with a short recovery interval (2 min). Similarly, some studies[34,35,36] demonstrated that the peak lactate response to RE was dependent, in part, on the amount of the work performed.

RE with the load of 80% of 1RM and higher and a low training volume derive most of the energy from the creatine kinase (CK) forms, the core of an energy network known as the phosphocreatine (PCr) system. Moreover, individuals who regularly participate in high-volume and intense exercise, tend to have significantly increased base levels of CK compared to sedentary and moderately exercising individuals[37]. It is known that RE also induces muscle damage as indicated by muscle micro injures[38], and increased serum CK activity[39,40,41].

In this context, fatigue in the max RPE is to a higher extent related to central fatigue[42]. Significant differences were observed with well-trained strength athletes between blood lactate during squats, bench press and lat pull–down exercises, because of the muscle mass involved and the position of the exercise. Body builders and power lifters reached blood lactate values of 15-17 mmol/L after six sets of squats with intensity of 70% of 1RM and 10-18 reps. The same protocol for the BP and LP induced lactate values of 8-10 mmol/L[42].

Results described by Lins-Filho et al.[43] showed a significant correlation among different intensities of the ER for young trained subjects. These results suggest that the RPE may be used to prescribe and monitor the intensity of multiple sessions of resistance exercise for young males with previous experience in RE. However, the results observed by those authors pointed to a significant association between the RPE and the intensity of 70% of 1RM, indicating that the scale tended to be more accurate at higher intensities than at lower ones. The fact is that the RPE is recommended for RE intensity control and not for intensity prescriptions[44].

Study Limitations

This study had some limitations. We need to emphasize a low sample size. However, other studies used similar sample sizes[45,46]. Although the sample size was small, it is believed that the findings of this research are applicable in the practical context of RE. Another issue that may be considered a limitation is that there was only one set of each exercise performed what did not stimulate glycolysis significantly, thus resulting in low LA concentrations.

Conclusions

In the present study, we questioned the existence of a significant relationship between blood lactate and the RPE obtained by the OMNI-RES scale. The results caused us to reject this hypothesis as there was no association among the studied variables. Considering the divergences found among these results and previous studies, it is necessary to be cautious when applying the OMNI-RES scale as a method for adjusting RE intensity. Further studies are recommended to analyze the influence of different variables related to RE execution on the perceived exertion.

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