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Original Article

EFFECT OF RESISTANCE EXERCISE WITH DIFFERENT MUSCLE ACTION DURATIONS ON LACTATE RESPONSE

EFEITO DE PROTOCOLOS DE TREINAMENTO COM DIFERENTES DURAÇÕES DAS AÇÕES MUSCULARES NA CONCENTRAÇÃO DE LACTATO SANGUÍNEO

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RESUMO

O objetivo deste estudo foi comparar a concentração de lactato sanguíneo em protocolos de treinamento de força com diferentes durações das ações musculares no exercício supino. Dezessete voluntários executaram três protocolos com três séries de seis repetições a 60% de 1RM, pausa de três minutos entre as séries e diferentes durações das ações musculares (2-4: 2s concêntrica e 4s excêntrica; 3-3: 3s concêntrica e 3s excêntrica; 4-2: 4s concêntrica e 2s excêntrica). A análise da concentração de lactato sanguíneo considerou os valores médios por série em cada protocolo. Os resultados da ANOVA *two-way* mostraram que o efeito principal protocolo não apresentou diferença significante entre os três protocolos (F = 0,75; p = 0,48; poder = 0,48; η^2 = 0,17), assim como para a interação entre os fatores (F = 1,68; p = 0,13; poder = 0,09; η^2 = 0,62). Porém, houve diferença significante na concentração de lactato sanguíneo para o fator série (F = 320,23; p = 0,0001; poder = 1,00; η^2 = 0,95). Portanto, protocolos de treinamento de força equiparados com durações das ações musculares distintas não apresentaram diferenças na resposta do lactato sanguíneo e, independentemente do protocolo, a concentração deste substrato aumentou ao longo das três séries realizadas.

Palavras-chave: Treinamento de força. Duração da repetição. Lactato sanguíneo.

ABSTRACT

The aim of this study was to compare the blood lactate concentration in strength training protocols with different muscle action durations in the bench press exercise. Seventeen volunteers performed three protocols with three sets of six repetitions at 60 % of 1RM, three- minute break between sets and different muscle action durations (2-4: 2s concentric and 4s eccentric; 3-3: 3s concentric and 3s eccentric; 4-2: 4s concentric and 2s eccentric). The analysis of blood lactate concentration considered the average values per set in each protocol. The ANOVA two-way of the results showed that the main effect for protocol showed no significant difference between the three protocols (F = 0,75; p = 0,48; power = 0,48; η^2 = 0,17), as the interaction among the factors (F = 1,68; p = 0,13; power = 0,09; η^2= 0,62). However, there was significant main effect for set (F = 320,23; p = 0,0001; power = 1,00; η^2= 0,95). Therefore, resistance training protocols equated with different muscle actions durations shows no differences in blood lactate response and, regardless of the protocol, its concentration increased throughout the three sets performed.

Keywords: Resistance training. Repetition duration. Blood lactate.

Introduction

The blood lactate is a sub-product of the glycolytic anaerobic system which has its concentration changed according to the metabolic demand of an exercise [1]. The blood lactate concentration has been used as a parameter for the metabolic response provided by different resistance training protocols[2-4]. Studies have associated the high response of blood lactate concentration to an increase in the fast twitch motor units recruitment[5,6], and to a greater hypertrophic response[7]. Considering that muscle fibers recruited during the resistance training are susceptible to adaptation[8,9], protocols which present a greater electromyographic response and higher blood lactate concentration would have major potential to promote largest increases in strength and muscle hypertrophy[7,10].

The prescription of a resistance training program should take into consideration different variables, and the manipulation of these variables (*i.e* repetition durations), can interfere in the electromyographic activity[,11,12] and in the blood lactate concentration[7]. Studies have been investigating the different responses of blood lactate concentration according to the manipulation of the resistance training protocols. Hunter et al.[13] verified that, concerning protocol with concentric muscle action durations of 2 seconds (s) and eccentric of 3s, the lactate concentration was approximately twice higher compared to super slow training, with concentric action of 10s and eccentric of 5s. The authors have justified the lower blood lactate concentration in super slow training due to lower intensity compared to other protocol. Durand et al.[14] have registered that the blood lactate concentration immediately after and 15 minutes after the concentric exercise was higher when compared to the exercise that used only eccentric action. This result suggests that a protocol with longer concentric action durations could result in higher lactate concentrations, as the total repetition duration would take a longer muscle action.

Goto et al.[15] have analyzed three training protocols with the same repetition duration, but different muscle action durations: concentric (CON) 5s and eccentric (ECC) 1s (5-1); CON 1s and ECC 5s (1-5); CON and EC C 3s each (3-3). The results showed higher blood lactate concentration in the protocol with longer concentric action duration (5-1), despite the lower repetition numbers, comparing to protocol 1-5. Considering the maximum eccentric force is approximately 30-50% higher than the maximum concentric force[16], the result in the blood lactate verified for the protocol 5-1 can be related to the fact that the exercise was performed during a longer period using the concentric action, where a higher relative intensity in comparison to eccentric action can be verified.

Tanimoto e Ishii[17] have demonstrated that the use of repetition duration of 7s at 50% of 1RM resulted in a blood lactate concentration similar to repetition duration of 3s at 80% of 1RM. The authors have also verified a similar increase in the cross-sectional area after 12 weeks of training using both protocols, a result of greater magnitude than another with duration of 3s and 50% of 1RM. In addition, have also verified that higher intensity or longer repetition duration result in blood flow restriction and lower oxygenation level, what leads to an increase in the blood lactate concentration. Therefore, this result suggests that a longer repetition duration can allow a protocol with lower intensity to result in a similar hypertrophic response to the one obtained with a higher intensity protocol.

Considering the protocols used in this study, remaining to be investigated if the protocols with lower magnitude difference in muscle action duration would be able to provide different blood lactate concentrations; the prescription of resistance training is usually done with subtle manipulations in this variable, for instance, 1-2 and 2-2. Moreover, studies that not equated other variables did not allow to verify the isolated effect in manipulating the repetition durations or the muscle actions. Therefore, the aim of the present study was to compare the blood lactate concentration in resistance training protocols equated with different muscle action durations in the bench press exercise, suggesting that there will be higher concentration of this anaerobic metabolism co-product in the exercises with longer concentric action duration. Then, establishing a relation among the varied training protocol configurations (in this case, duration of muscle actions) and the acute blood lactate concentrations will contribute to enhancing the understanding about the organic responses to strength stimuli.

Methods

Participants

All of the 17 male volunteers who took part in this study have weight training experience for at least 6 months and did not report having any history of muscle-tendinous injury in the shoulder, elbow or handle articulations and most of them (70,6%) stated that they did bench press exercise in their current training. All of them have previously received information concerning the data collection procedures and they have signed the Inform Consent Form. The study was approved by the Research Ethics Committee of the Federal University of de Minas Gerais (report ETIC nº 0279.0.203000-10).

Procedures

The subjects were submitted to all the protocols and had their measures undertaken throughout the sessions, being, this way, their own control[18]. The 1RM tests and the protocols were performed using a 20kg-barbell Master Equipment and a horizontal bench. Weight plates were also used and their mass checked by a FILIZZOLA (O. Filizzola & Cia. Ltda, São Paulo, SP, Brasil) scale, previously calibrated for the external resistance adjustment. To analyse the blood lactate concentration a *Yellow Springs* (YSA, Inc., Yelow Springs, OH, EUA) was used, model *Sport* 1500.

The volunteers came to the laboratory in 5 different days (5 sessions), with an interval of, at least, 48 hours between them. On the first day, each volunteer read and signed the Inform Consent Form and after that, the standardization of position on the equipment, as well as of the extent of the movement on the barbell, were done. The upper limit of the movement extent was determined to the point of the full extension of the elbows and the lower limit was determined using a rubber fixed on the sternum. The volunteers also got familiarized with the 1RM test within six attempts to identify the maximum weight the subject could lift in one single repetition[19] with a break of 3 to 5 minutes between them. Subsequently, they got familiarized with the durations of muscles actions: 4-2 (4s concentric e 2s eccentric); 3-3 (3s concentric e 3s eccentric); 2-4 (2s concentric e 4s eccentric) in a random order balanced among the volunteers along the sessions 1 e 2. This familiarization happened 10 minutes after the one with the 1RM test and consisted of the same training protocols 1RM: three sets of six repetitions with 60% of the 1RM value and a pause of 180 seconds. In the second session, the 1RM was done to determine the corresponding weight according to the intensity used in the training protocols (60% de 1RM).

From sessions 3 to 5 training protocols for bench press were performed. Before the data collection the electro goniometer was placed to obtain the repetition duration. The electrogoniometer (NORAXON, Scottsdale, AZ, EUA) was calibrated using a manual goniometer, and the calibration correction value stored for future analyses. The electrogoniometer was affixed to the left elbow of the subject, using double sided adhesive tape and elastic bands. After being stored, the raw data registered by the electrogoniometer were converted to angular displacement and filtered through a fourth order *Butterworth* filter, low-pass corner frequency of 10Hz. An appropriate software was used to register and treat data (DasyLab 11.0; Measurement Computing Corporation, Norton, MA, EUA).

The electrogoniometer was also used to determine the elbow range of motion. Moreover, the repetition duration was determined by the time of the angular displacement. The duration of the concentric muscle action encompassed the time spent with the barbell displacement between the position of the greater elbow flexion in the end of the eccentric action, at the moment the barbell touched the device put on the subject chest and the position of the greater extension of the elbows (approximately 180º) at the final moment of the concentric course of the barbell. The duration of the concentric action encompassed the opposite way of the barbell displacement described. It is worth pointing out that the elbow angulation at the end of the eccentric action has shown some variation according to the volunteer stature.

After the procedures of electrogoniometer's placement, the volunteer remained resting for 10 minutes for blood collection and performed on the training protocols subsequently. The subjects performed the protocols randomly and in balanced way. The protocol configurations where determined taking into consideration the resistance training recommendations aiming at muscle hypertrophy[20,21]. In order to maintain the muscle action duration according to recommendations, the volunteers counted on the help of a metronome and received oral feedback from the researchers. The interruption in training sessions occurred in the following situations: either the subject did not maintain the muscle action duration for two consecutive repetitions or did not perform the extent of the movement according what was determined in the first session. This way, it was possible to investigate the acute effect of training protocols with 6s repetition duration and different muscle action durations concerning blood lactate concentration.

The data were collected at the same time of the day during the different collection sessions for each volunteer and they should not perform the training using neither the pectoralis major, triceps nor anterior deltoid muscles 48 hours before the collection sessions. The volunteer received the suggestion to keep the same diet during the data collection period.

During session 3 and 5 volunteers had their blood collected to measure lactate concentration. The collection happened in four moments: after a 10-minute rest period before the performance of the protocol, in which the subject remained seated and 1 minute after finishing each of the three sets. The blood was collected from the left earlobe after drilling with disposable sterilized lancets from Accu-Chek Softclix Pro Roche (Roche Diagnóstica Brasil Ltda, Jaguaré, SP, Brasil). Heparinized blood samples of 30 µl were used through capillaries and stored in plastic tubes from Eppendorf (Eppendorf do Brasil, São Paulo, SP, BRA) with 60 µl of sodium fluoride (1%) at the temperature of -20º for later analysis using Yellow Springs, 1500 Sport.

Statistical analysis

The normality of data distribution and sphericity was verified through *Shapiro-Wilk* and *Bartlett* tests, respectively. To analyze the blood lactate concentration and repetition durations ANOVAs *two-way* was used, with repetitive measures (factor 1: protocol, factor 2: set). To compare muscle action durations ANOVA *three-way* was used, with repetitive measures (factor 1: protocol, factor 2: set, factor 3: muscle action). Finally, to analyze the movement amplitude performed during the concentric and eccentric actions ANOVA *two-way* was used, with repetitive measures (factor 1: protocol, factor 2: set). When necessary, *post hoc* Tukey was used to identify the differences reported by ANOVAs.

The statistical tests were done using *STATISTICA* program, version 7.0 for Windows (STATSOFT, Tulsa, OK, EUA). The data were presented as means and standard-deviations. The level of significance adopted in the analyses was $p < 0{,}05$.

Results

The ANOVA *two-way* results for the analyses of blood lactate concentration are shown in Figure 1. The main effect of the protocol did not present any significant difference in blood lactate concentration among protocols 2-4, 3-3 e 4-2 ($F = 0{,}75$; $p = 0{,}48$; power = 0,48; $\eta^2 = 0{,}17$), as well as for the interaction among factors ($F = 1{,}68$; $p = 0{,}13$; power =

0,09; $\eta^2 = 0,62$). However, there was a significant main effect for set (F = 320,23; $p = 0,0001$; power = 1,00; $\eta^2 = 0,95$). The *post hoc Tukey* test has indicated that the blood lactate concentration values after each of the three sets were statistically different among them, and there was a considerable increase along the sets, in other words, the 3rd set was higher than the 2nd one, which was higher them the 1st one. All of the three sets have presented higher values of blood lactate concentration than the resting period. (Figure 1).

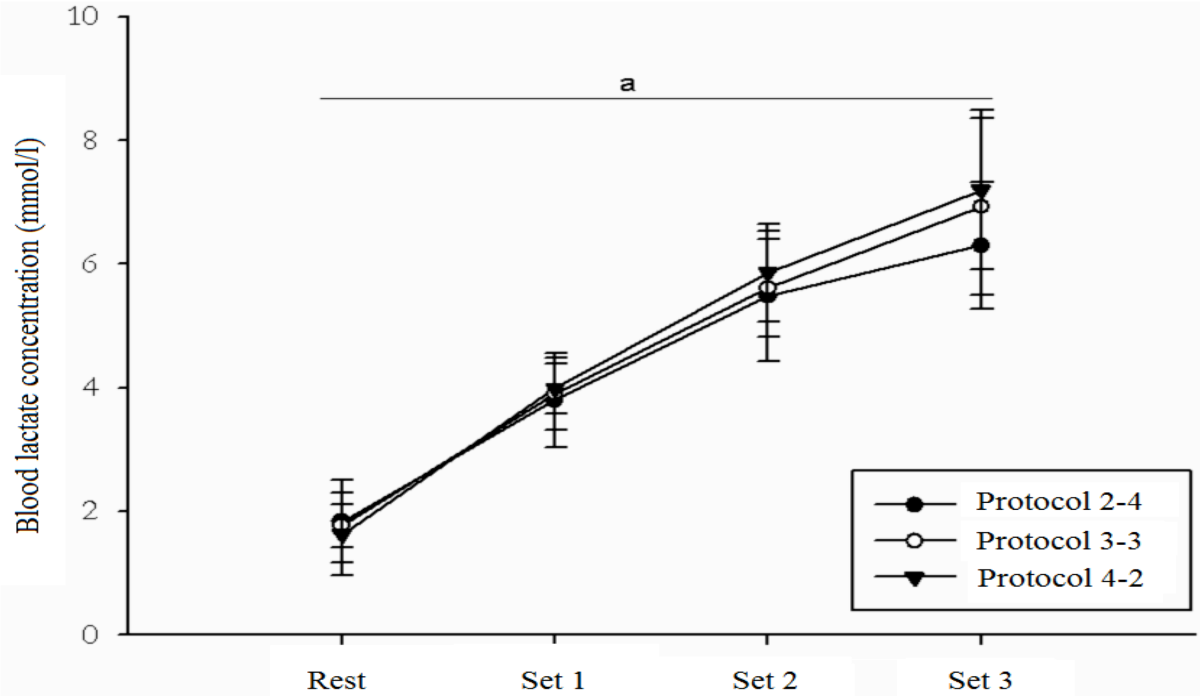

Figure 1. Blood lactate response at rest and along the three sets to protocols 2-4, 3-3 e 4-2. [a] Increase in the blood lactate concentration along the sets (Rest < Set 1 < Set 2 < Set 3).
Source: The authors

According to what was expected, the durations of repetitions did not show significant differences among the protocols (F = 0,05; $p = 0,95$), with averages of 5,99s; 6,00s; 5,99s, for protocols 2-4, 3-3 e 4-2, respectively. In addition, variation coefficients lower than 4% were verified for all of the investigated protocols. The muscle action durations verified in each set meet expectations, that is to say, the durations of 2s were lower than the 3s and 4s, and the duration of 3s was lower than of 4s, regardless of the muscle action of the training protocol (F = 15,3; $p < 0,05$). In protocols 2-4 e 4-2, the muscle action duration of 2s were not significantly different, as well as the one of 4s. Likewise, protocol 3-3 did not present any significant difference among the muscle action durations ($p > 0,05$). Therefore, the use of metronome and the researches feedback were effective as means to help in control of repetition durations and eccentric and concentric muscle action durations.

The data concerning the range of motion performed during concentric muscle actions (58,97 ± 11,0°; 60,94 ± 10,9 °; 59,23 ± 13,5°; F = 0,8; p = 0,4) and eccentric (59,27 ± 11,0°; 60,97 ± 10,7°; 59,38 ± 13,5°; F = 0,6; p = 0,6) did not present significant differences when comparing training protocols 2-4, 3-3 e 4-2, respectively. Thus, it is possible to consider that the range of motion has remained constant in all the training protocols investigated.

Discussion

The present study has not found differences in blood lactate concentration among protocols with different concentric and eccentric muscle action durations and the same repetition durations. Still, it has registered a rise in this concentration along the performance of 3 sets of 6 repetitions at 60% of 1RM and 180s pause between sets.

Exercises involving only concentric actions have registered a higher blood lactate concentration comparing to exercises involving only eccentric actions[14]. Considering the blood lactate as a marker of the metabolic activity demand and that the concentration of this sub-product can increase 1 minute the end of the effort[4,22], the expectancy of the present study was to find a higher concentration of this sub-product in protocols with longer concentric action duration. However, the results did not confirm this hypothesis.

Goto et al.[15] have compared protocols with greater differences in muscle action durations than the ones in the present study. These authors have used three protocols with concentric and eccentric durations with values of 5s:1s, 1s:5s and 3s:3s respectively and they have registered significant difference in blood lactate response, with higher values for the protocol 5s:1s. The result found in the present study can suggest that the difference in the concentric actions duration (2s x 3s x 4s) were not enough to induce these significant differences in the concentration of this metabolite.

The data in the present study do not corroborate with González-Badillo et al.[23] results, which have registered a higher blood lactate concentration in protocol with shorter concentric action duration compared to another one with longer duration of this muscle action and similar eccentric action durations. These authors have used, concerning bench press exercise, equalized protocols for all the other variables and have used 3 sets with a repetition numbers that corresponded to half of the maximum number of possible repetitions (MNR), with pauses of 3 minutes between sets and intensity between 60% and 80% of 1RM. Although the difference in blood lactate concentration is of low magnitude, the authors point out that the shorter concentric action duration (faster movement speed) would result in a greater fast twitch motor units recruitment. However, these authors have used explosive movements, what can restrict the comparison with data of the present study. This motor units have presented a greater glycolytic demand to produce energy, what would explain the higher concentration of lactate in this protocol. Pareja-Blanco et al.[24] have got a similar result using back squat exercise with similar methodology to González-Badillo et al.[23] study.

The results of the present study, as well as the other presented, point out contradictory answers of blood lactate response relating to the muscle action duration. The differences in sizing of the duration and the other training load components can justify the inconsistency of the obtained data. The discussion presented in González-Badillo et al.[23] e Pareja-Blanco et al.[24] studies support the higher values of blood lactate concentration in shorter concentric durations due to the greater use of fast twitch motor units to perform a task in higher speed. However, the magnitude of the difference in blood lactate concentration comparing shorter and longer concentric durations was moderate ($4{,}7 \pm 2{,}0$ mmol $\cdot$ L^{-1} and $3{,}2 \pm 1{,}7$ mmol $\cdot L^{-1}$, respectively). It is worth pointing out that these studies have used a reduced repetition numbers, not getting close to fatigue in each set. On the other hand, Goto et al.[15] study have used training protocols until fatigue, performing the MNR in each set, what rises considerably the demand in each set when compared to the other two studies that did not use the MNR. This difference in the repetition numbers among the mentioned studies can have contributed to the divergent results. The protocols of the present study did not anticipate the performing of the MNR, but it was observed that the volunteers, in many sets, had lots of difficulties to finish the 6th repetition keeping the expected repetition duration. This fact has suggested the idea that, most probably, it would not be possible to perform the additional repetition in moments like that.

In the present study, a significant main effect for set was identified, with the increase of blood lactate concentration along the sets, regardless of the protocol. It can have been caused by the 6s repetition duration, which resulted in an increasing demand for the subjects, as they were used to training with shorter duration than the one adopted for the research. In addition, the rise in blood lactate concentration verified along the sets is consistent with the outcome of the results obtained by Lacerda et al.[4]. These authors verified a rise in blood lactate concentration and muscle activation in both training protocols of three sets: 6 repetitions and repetition duration of 6s and in the other one with 12 repetitions and repetition duration of 3s. Considering a higher muscle activation in each sets as a result of a greater recruitment of traction units and a gradual increase of greater fast twitch motor units recruitment, a progressive rise in the blood lactate concentration along the sets would be expected. This prospect progressive rise is related to a higher capacity of strength production and energy supply through glycolytic pathway[26]. Also, this sub-product concentration might be increased throughout the sets, in other words, the value registered in the end of the third sets would not represent the resultant concentration of this sets demand only. Therefore, it can be speculated that the training load regarding the protocols investigated in the present study might have demanded a strategic change of muscle activation so that the mechanic work related to each set was performed. Although the interval has been enough for both protocols to be performed, the pause duration of 180s would not have been enough for a proper recovery of the fast twitch motor units, demanding a gradual increase in the recruitment of other fast twitch motor units with glycolytic pattern to supply the body need to perform the same mechanic work throughout the sets. The results of the present study reinforce this argument.

The present study has concluded that bench press training protocols with equivalent volume, intensity, pause and repetition durations, but with different concentric and eccentric muscle action durations, do not result in different values of blood lactate concentration. This finding has not confirmed the hypothesis that a longer concentric action duration would result in a higher concentration of this metabolite. Also, regardless of the muscle action durations, an increase in the blood lactate concentration happens along 3 set with 180s pause between them.

The difference in muscle action durations among protocols might not have been enough to cause different metabolic responses. Therefore, we suggest that other studies continue the investigation toward the use of different muscle action durations, as well as protocols with maximum repetition numbers.

Conclusions

The present study has concluded that, for a 6s repetition duration, the different muscle action durations adopted result in similar values to blood lactate collected 1 minute after each of the 3 sets of exercise. Taking these results into consideration, it is suggested the adoption of a combined manipulation of other variables and/or a validation of the electromyographic response and strength performance in protocols distinguished by the muscle action durations.

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