The acute effects of varied resistance training methods on blood lactate and loading characteristics in recreationally trained men

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ABSTRACT

Several resistance training methods (RTM) have been developed in order to manipulate physiological stimuli and obtain better results with training. The purpose of this study is to compare the metabolic and mechanical responses among seven different RTM reported in the literature. The RTM were compared with regard to blood lactate, time under tension (TUT) and total loading (TUT x load) in recreationally trained young men. The RTM tested were 10RM (TEN), super-slow (SL), functional isometrics (FI), adapted vascular occlusion (VO), 6RM (SIX), forced repetitions (FR) and breakdowns (BD). All RTM produced significant increases in blood lactate, with no difference among them. The BD method elicited higher TUT and total loading compared to the other RTM tested.

Keywords: Strength training. Muscle hypertrophy. Acute responses. Blood lactate. Work.

INTRODUCTION

Resistance training has a fundamental role in physical activity programs, and has been recommended by many major health organizations in order to increase general health and fitness(1-5). Two of the most common goals of resistance training are increases in muscle strength and hypertrophy with athletic, aesthetic or health purposes as in chronic conditions such as sarcopenia and AIDS(6-9).

The results obtained with resistance training is influenced both by mechanical and metabolic stimuli. Mechanical stimuli is directly influenced by the amount of weight lifted in each repetition and by the number of repetitions performed per set, and is often believed to be one of the major determinants of the resistance training adaptations(10-12). However, some studies suggest that metabolic changes play an important role in gains of muscle size and strength, even when reduced work volume is performed(13-16).

With the purpose to manipulate training stimuli and to attain better results, several resistance training methods (RTM) have been developed. The RTM have manipulated training variables in different ways, providing mechanical and metabolic stimuli of different magnitudes. It is also important to know how each RTM acts in order to design resistance trainings with maximal efficiency and safety.

Studies comparing different RTM have been reported in the literature. Ahtiainen *et al.*(17) compared the acute and neuromuscular responses between forced repetitions (FR) method and a 12 maximum repetition (12RM) method, and found greater loading for the FR method with no significant differences for blood lactate levels. Hunter *et al.*(18) compared the metabolic and heart rate responses between the super-slow (SL) and the 10 maximum repetitions (10RM) methods and found significant higher lactate levels for the 10RM method. However, Keogh *et al.*(19) did not report any significant differences in blood lactate concentration between the SL and the 10RM method.

Thus, due to the contradiction between the findings of Keogh *et al.*(19) and Hunter *et al.*(18), as well as, the lack of studies comparing physiologic stimuli among other RTM, the purpose of the present study was to compare the metabolic and mechanical responses among seven different RTM reported in the literature.

METHODS

Subjects

Seven recreationally weight-trained men with at least one year of experience in the RTM tested were recruited to participate in this study. The minimum overall resistance training experience required to enter the study was two years. All subjects were informed of the risks and benefits of the experiment and signed an informed consent form before participation in the study. The study was approved by the Ethics Committee of Universidade de Brasília.

Resistance training methods (RTM)

All RTM were performed in a knee extension machine. The seven RTM analyzed in this study were:

1) 10 maximum repetition method (TEN): Normal isoinertial lift at 10RM load conduced until concentric failure is reached.

2) 6RM maximum repetition method (SIX): Normal isoinertial lift at 6RM load conduced until concentric failure is reached.

3) Breakdown method (BD): Repetitions were performed at 6RM load until concentric failure. After failure, load was reduced by 5.0 kg and exercise continued, the procedure was repeated until 15 repetitions were reached. A mean of 4.14 ± 0.9 load reductions were performed during BD method.

4) Forced repetitions method (FR): A set was conduced at 6RM load until concentric failure was reached. After failure, four more repetitions were performed with assistance. Assistance was given only at the concentric phase and the same exercise technologist assisted all subjects.

5) Functional isometrics method (FI): Normal isoinertial lifts were conduced at 10RM load until concentric failure. In each repetition a five seconds isometric contraction at maximal knee extension was executed.

6) Adapted vascular occlusion (VO): A 20-seconds maximal isometric contraction at 10RM load was immediately followed by nor-

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mal isoernitial lifts at 10RM load until concentric failure. This method is often used in order to obtain the benefits of vascular occlusion[15-16,20], since isometric actions are known to be effective in interrupting blood flow and accumulating metabolites[21-22].

7) Super-slow method (SL): It was performed one set comprising one 60-second repetition with 30 seconds for both eccentric and concentric phases. To control velocity, time was informed every five seconds.

Testing procedures

Tests were conduced in a leg extension machine (HN1030, Righetto, São Paulo-Brasil). On the week before the experiment a 10 repetitions maximum (RM) and a 6RM load for each subject was assessed according to the procedures reported by Simão *et al.*[23].

All seven subjects executed the seven RTM in a randomized order. RTM tests were performed over two weeks: week 1 included VO, FI, SL and TEN, week 2 involved BD, FR and SIX. Four subjects executed week 1 before 2; and the remaining three execute the inverse order: week 2 before week 1 (figure 1). RTM order was randomized during each week, with a minimum of 24 and a maximum of 48 hours interval between tests. Subjects were instructed to avoid any type of resistance training involving the quadriceps muscles 24 hours prior to the tests.

Week 1							Week 2				
↓ Day 1	24-48hr	↓ Day 2	24-48hr	↓ Day 3	24-48hr	↓ Day 4	↓ Day 1	24-48hr	↓ Day 2	24-48hr	↓ Day 3
Methods: 10RM. adapted vascular occlusion. functional isometrics. super-slow							Methods: 6RM. drop-set. forced repetitions				

Figure 1 *– Experiment design*

TEN (10RM), SL (super-slow), FI (functional isometrics), VO (adapted vascular occlusion), SIX (6RM), BI (bi-set), FR (forced repetitions), BD (breakdowns).

In all RTM, except SL and specific isometrics moments on FI and VO, subjects were instructed to maintain a constant velocity of two seconds in the concentric phase and two seconds in the eccentric phase, with no pause between phases. The concentric phase started at 100º of knee flexion and ended with the knees fully extended. A metronome was used to control contraction velocity.

Blood lactate measurements

A small sample of blood (25 µl) was taken from the right ear lobule immediately before and three minutes after the completion of each RTM for the determination of blood lactate. Blood from these incisions was allowed to flow into a Brand NH4 heparinized capillary tube. From the capillary tube, the blood was added to a labeled Eppendorf tube filled with buffer at a ratio of 1:3 (blood to buffer). These samples were then placed in refrigeration at approximately 4ºC for approximately 30 minutes and then put in a refrigerator. Blood samples were analyzed using the YSI 1500 Lactate Analyzer (Yellow Springs Instrument Co., Yellow Springs, OH).

Loading assessment

Time under tension (TUT) was defined as the total time in which the muscles were applying force to the implement during the performance of each RTM. The same investigator recorded the time of all tests using a digital chronometer. Additionally, it was used the product "time under tension × load" to estimate total loading imposed to working muscles.

Statistical analyses

Standard statistical methods were used for the calculation of means and standard deviations. Differences between RTM for lactate response, TUT and loading, were assessed using Friedman test. Wilcoxon Sign-Ranks test with adjustment of confidence interval by Bonferroni method, was used for post-hoc comparisons. The $p \leq 0.05$ criterion was used for establishing statistical significance.

RESULTS

Physical characteristics of subjects are presented in table 1.

TABLE 1
Physical characteristics of the subjects

Variable	Mean ± SD
Age (years)	24.14 ± 3.18
Weight (kg)	77.33 ± 8.71
Height (cm)	177.86 ± 7.66
Knee extension 6RM load (kg)	128.57 ± 8.02
Knee extension 10RM load (kg)	105.00 ± 14.14

Blood lactate

Results from blood lactate responses are presented in figure 2. All RTM significantly elevated blood lactate from rest levels ($p < 0.01$), however there were no differences in blood lactate response among all RTM ($p > 0.05$).

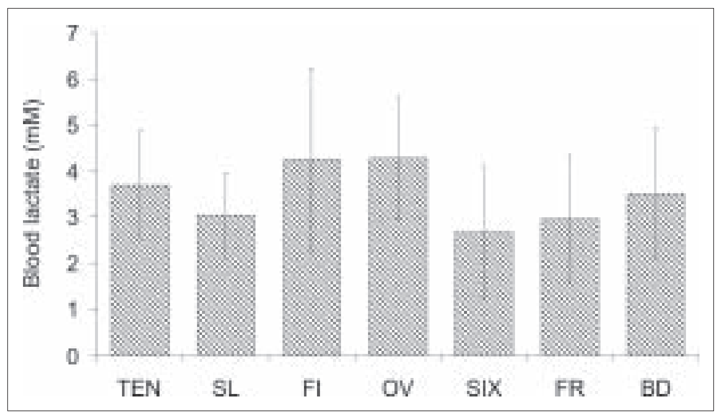

Figure 2 *– Blood lactate responses for each resistance training method*

TEN (10RM), SL (super-slow), FI (functional isometrics), VO (adapted vascular occlusion), SIX (6RM), BI (bi-set), FR (forced repetitions), BD (breakdowns).

Loading characteristics

TUT and total loading results are presented in table 2. TUT for the BD was greater than for all the remaining methods ($p < 0.05$). TUT for SL method was greater than TEN, SIX, FR and VO. TUT

TABLE 2
Time under tension and total loading ("time under tensio × load") during different methods

Resistance training methods	Time under tension (s)	Total loading (kg.s)
10RM (TEN)	40.28 ± 2.06[2]	4357.14 ± 772.83
Super-slow (SL)	60 ± 0[1,2,5,6]	6471.43 ± 962.14[1,2,5]
Functional isometrics (FI)	58.43 ± 5.19[1,2,6]	6308.57 ± 1135[1,2]
Vascular occlusion (VO)	56 ± 3.37[1,2,6]	6051.43 ± 1046.07[1,2]
6RM (SIX)	29.86 ± 2.19	3892.86 ± 497.89
Forced repetitions (FR)	45.43 ± 6.05[1,2]	5832.86 ± 768.19[1,2]
Break downs (BD)	68.86 ± 9.51[1,2,3,4,5,6]	8939.79 ± 964.91[1,2,3,4,5,6]

1 – significantly higher than TEN ($p < 0.05$); 2 – significantly higher than SIX ($p < 0.05$); 3 – significantly higher than SL ($p < 0.05$); 4 – significantly higher than FI ($p < 0.05$); 5 – significantly higher than VO ($p < 0.05$); 6 – significantly higher than FR ($p < 0.05$).

values for FI and VO methods was greater than TEN, SIX and FR ($p < 0.05$). FR method elicited greater TUT than TEN and SIX; and TEN method elicited greater TUT than the SIX method ($p < 0.05$).

Total loading applied to the muscle, expressed as the product "time under tension × load", was greater for the BD method than for all the others RTM ($p < 0.05$). Total loading during the SL was greater than TEN, SIX and VO methods. Loading for FI, VO and RF methods were greater than TEN and SIX ($p < 0.05$).

DISCUSSION

The lack of differences for blood lactate responses among the RTM tested in the present study is in agreement with previous findings[17,19]. However, the conclusions are limited due to the reduced number of subjects and the large inter-individual variations in lactate responses. Moreover, a retrospective analyses of the statistical power indicated a type II error rate, making the study underpowered at its completion, thus further work is warranted to resolve the issue of metabolite accumulation in different RTM.

Usually a set is ended when it is not possible to lift a predetermined load; BD method is designed to go beyond this point using load decrements to adjust the load to the muscle force capacity. In the present study, the BD method produced higher values of total loading and work performed than all other RTM. TUT for the BD was significantly higher ($p < 0.05$) to all other methods. These findings, associated with the significant metabolite accumulation during the BD method, makes attractive to speculate that this RTM is particularly efficient to induce gains in muscle size and strength, which is in agreement with previous studies[24-26].

When comparing the FR to SIX methods it was found that blood lactate response were not different between them, despite executing 77% more repetitions and work ($p < 0.01$) and been submitted to 52,14% more TUT ($p < 0.01$) during the FR method. The fact that the FR method did not produce superior lactate responses when compared to SIX is in agreement with previous findings[17] and it is not unexpected, since eccentric contractions have been shown to induce a decreased metabolic stress[19,27-29]. The rationale for using the FR method probably lies in the neuromuscular characteristics of eccentric actions. During the lowering phase of movement, more force could be exerted than during the concentric portion of the lift, thus even after concentric failure, it is possible to continue the exercise with eccentric actions, prolonging training stimuli. Since eccentric actions are known to cause more muscle damage[30-31] and activate mechanotransduction more than other phases of movement[32], the FR method should be used to stimulate these adaptative mechanisms, making it suitable to promote gains in strength and hypertrophy as suggested by Ahtiainen *et al.*[17].

The present findings did not show significant differences between blood lactate responses during the SL method and other RTM, contrary to previous findings[18]. TUT was significantly higher for the SL than for TEN, SIX, VO and FR methods and total loading was significantly higher than for TEN, SIX and VO methods. This could make the SL method useful for hypertrophy as suggested by Westcott *et al.*[33]. It is important to note that the SL method used in this study is notably different from others[18-19,33-34]. The SL protocol of Keeler *et al.*[34] and Hunter *et al.*[18] consisted of 10-second concentric and 5-second eccentric contractions at 50% and 28% of 1RM, respectively, while we used a load equivalent to 10RM with 30 seconds for both concentric and eccentric phases. Light loads could be the cause of reduced chronic adaptations seen by Keeler *et al.*[34] and low metabolic stress found by Hunter *et al.*[18]. It is important to note that SL training is associated with considerable discomfort, which can mask real exercise intensity and induce the use of lighter loads than the muscles can support, thus, care must be taken to not underestimate resistance load when using the SL method if one wants to improve muscle size and strength.

This is the first know study to analyze the VO method. TUT for the VO method was significantly higher than for TEN, SIX and FR methods and total loading was superior to the TEN and SIX methods ($p < 0.05$). Due to fatigue generated by previous isometric contraction, total repetitions fell considerably (22.9%) when compared to the TEN method, however TUT and total loading markedly increased (~39%). The VO method is based on the alterations in fiber recruitment pattern during contraction in ischemic conditions as suggested by Takarada *et al.*[15]. The rationale of this RTM is to perform a prolonged isometric contraction to induce ischemia, so that larger fast twitch fibers are preferentially recruited during subsequent contractions. It is not known, however, if this RTM would obtain chronic results comparable to those obtained with constant vascular occlusion via tourniquet as seen by Takarada *et al.*[15], Burgomaster *et al.*[16] and Shinohara *et al.*[20].

Previous studies found that the FI method was superior to traditional strength training programs in increasing muscle strength[35-36], especially in stronger subjects[37]. In addition to strength gains in specific joint angles suggested by Fleck and Kraemer[38], this could be due to higher TUT and total loading achieved with this method in comparison to traditional approaches (TEN and SIX), as seen in the present study. Additionally, ischemia caused by maximal isometric contractions could also act as a metabolic stressor in order to improve adaptations similar to that seen in studies using vascular occlusion[15-16,20].

During comparison between two traditional RTM (TEN vs. SIX), it was found that total work was significantly higher to TEN when compared to the SIX method ($p < 0.05$), however differences in total loading were not significant. Blood lactate response were not different between TEN and SIX methods, although mean blood lactate response for the TEN method was 39% higher to the SIX method. Kraemer *et al.*[39] tested heavy resistance training protocols with multiple sets and exercises and did not found differences in blood lactate response between protocols using 5RM or 10RM when a 3-minute rest period length was used between sets and exercises, however there were significantly higher blood lactate responses during the 10RM protocol when 1-minute rest interval was given. These results suggest that blood lactate accumulation in strength-trained individuals is more evident with multiple sets and shorter rest intervals.

Future studies should use other methods to measure both physiologic (i.e: muscle protein synthesis and specific RNAm of proteins of interest) and mechanic characteristics of the RTM in larger samples. Also, long-term studies are needed to evaluate chronic adaptations to different RTM in order to test if the acute differences in selected physiological parameters reflects in chronic adaptations to training.

CONCLUSIONS

In conclusion, all RTM produced significant elevations in blood lactate levels from rest, however there were no differences in blood lactate responses among all RTM. These results indicate that all RTM seems to provide the same metabolic stimuli. Regarding mechanical stimuli, BD produced higher loading than all other RTM. Additionally, loading during SL, FI, OV and FR were greater than loading during TEN and SIX methods.

In practical terms, when the training goal is to provide metabolic stimuli, all RTM seems to be equally efficient. If the purpose is to induce greater mechanical stress, BD seems to be the more indicated.

All the authors declared there is not any potential conflict of interests regarding this article.

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