Recovery Oxygen Uptake in Response to Two Resistance Training Sessions at Different Intensities

EXERCISE AND SPORTS SCIENCES

ORIGINAL ARTICLE

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ABSTRACT

The purpose of the present study was to compare the oxygen uptake ($\dot{V}O_2$) behavior in response to a resistance exercise (RE) session with aim of hypertrophy (HP) with another session with aim of local muscular endurance (LME). Nine young men (23.1± 2.1 years) voluntarily participated in the present study. Dynamic muscle strength was measured with one repetition maximum test (1RM). O $\dot{V}O_2$ was collected at rest and ten minutes after exercise with a gas analyzer (CPX/D). The RE protocols were composed of one upper body exercise (bench press) and one lower body exercise (squat) with the execution of 3 sets of 6-8 maximum repetitions (RM) with 80% of 1RM in HP session and 3 sets of 15-20 RM with 55% of 1 RM in LME session. Exercise post oxygen consumption (EPOC), energy cost (EC) and time constant (TC) of $\dot{V}O_2$ were analyzed. The results showed that both RE sessions provoked significant elevated $\dot{V}O_2$ after RE in comparison to rest values. There were no differences between groups in the EPOC (l) (HP: 2.21 ± 0.54 vs. LME: 2.60 ± 0.44), EC (Kcal) (HP: 10.36 ± 2.53 vs LME: 12.18 ± 2.04) and TC of $\dot{V}O_2$ (s) (HP: 56 ± 7 vs. LME: 57 ± 6) ($p>0.05$). These results demonstrated that a RE session with the aim of LME gain is capable of causing similar metabolic impact to the RE session with HP aim, even if it is performed at lower intensity concerning maximal load.

Keywords: muscle hypertrophy, local muscular endurance, EPOC, energy cost, $\dot{V}O_2$ kinetics.

INTRODUCTION

Oxygen consumption ($\dot{V}O_2$) is a valid and widely used physiological parameter in the investigation of the post-exercise metabolism, where excessive oxygen consumption after exercise is named EPOC (excess post-exercise oxygen consumption). High $\dot{V}O_2$ after physical exercise performance is derived from all factors responsible for the alteration of the mitochondrial respiration. The alterations in the ADP, ATP, Pi and CP concentrations are the direct factors, while the indirect factors are the catecholamines, tiroxine, glucocorticoids, fatty acids, calcium ions and body temperature[1].

Many investigations about the EPOC response to strength exercises have been carried out[2-6], and intensity is the most manipulated variable in these studies, in which the high intensity sessions demonstrate higher EPOC response[6]. Most part of the investigations performed about this topic chose to control toning, that is to say, to vary intensity and volume between sessions with no alteration in total muscular work (load x nº of repetitions)[4,7,8]. In a study by Thornton and Potteiger[4], comparing two sessions of same work and different intensities, it was demonstrated that high intensity session caused higher EPOC compared to the low intensity one. In a study conducted by Olds and Abernathy[8], differences in the EPOC responses between high and low intensity sessions have not been found. However, these authors used too close intensities relative to maximum load intensities, which may have influenced in the similarity of EPOC at the different intensities. Further studies which compared resistance exercise sessions (RE) and aerobic exercises (AE), found higher EPOC values for the RE sessions compared to the AE sessions [9,10]. Thus, RE seems to represent higher intensity compared to continuous aerobic exercises, causing more severe homeostatic disorders to the recovery metabolism.

Manipulation of acute variables of the resistance training such as volume, intensity and recovery interval, causes different neuromuscular responses. Therefore, higher intensities concerned with maximum strength and low number of repetitions cause greater adaptations in maximum strength and muscular hypertrophy (HP) while low intensity training with high number of repetitions results in greater gain of local muscular endurance (LME)[11]. It is also widely described that, in resistance training, the greater the stimuli (specific for each aim), the higher the adaptations will be. Thus, many authors are for the work at maximum repetitions (RM), which comprehend the performance of the highest number of repetitions as possible at the proposed intensity. This methodology proposes

that physical capacity being it maximum strength, power or LME, should be always worked at 100% of the physiological intensity, for stimuli optimization [11,12].

Although some studies have investigated EPOC after resistance exercise (RE) sessions, few of them were performed with the aim to compare RE sessions with different aims (e.g. hypertrophy, local muscular endurance),performed with maximum repetitions for each intensity concerned with maximum load. In the studies which compared the effect of different RE sessions in EPOC[4,8,9], the training session intensity and volume used by these authors was lower than the values recommended to reach aims such as LME increase and HP, which makes the practical application of these sessions limited. Thus, the aim of the present study was to compare the $\dot{V}O_2$ physiological responses and energetic cost after performance of two resistance exercise sessions with different aims, namely muscular hypertrophy and local muscular endurance, using maximum repetitions within the intensity interval specific for these adaptations.

MATERIALS AND METHODS

Experimental Outlining

Each individual visited the Physical Education School (EsEF) of the Federal University of Rio Grande do Sul (UFRGS) in three different occasions for data collections. During the first visit, the anthropometric characteristics were measured and the maximum dynamic muscular strength tests performed in two exercises (bench press and squat). In the two following visits the experimental sessions of resistance exercise were randomly performed with different aims: muscular hypertrophy (HP) and local muscular endurance (LME). Session order was random and all individuals performed the tests between 8 and 11 o'clock in the morning. A minimum interval of five days was respected between each visit.

Sample

The study sample was composed of nine healthy men. The characterization variables are presented in table 1. The individuals participants in the study were familiarized with the resistance exercise (RE) used in this study, but had not been engaged in any kind of resistance training for at least six months. The exclusion criteria of the sample were: neuromuscular injury history, cardiorespiratory diseases, metabolic and/or of the endocrine system disorders, chronic medication administration or at seven days from the data collection and, finally, any other infectious and/or inflammatory episode. All individuals signed the Free and Clarified Consent Form and the present study was approved by the Committee of Ethics in Research of the Federal University of Rio Grande do Sul.

Table 1. Anthropometric characteristics of the sample (mean ± SD).

Characteristics	Mean ± SD
Age (years)	23.1 ± 2.1
Stature (cm)	173.4 ± 7.5
Mass (kg)	70.9 ± 5.2
% fat	16.9 ± 3.5
% lean mass	83.1 ± 3.7

*Indicates significant differences between HP and LME.

Anthropometric Measurements

Body mass and stature were measured with an analogical scale and a stadiometer (resolution of 0.1kg and 1mm, respectively), both by ASIMED. Body density (BD) was estimated using the skinfold protocols proposed by Jackson and Pollock[13]. Subsequently, body composition was estimated with Siri apud Heyward and Stolarczyk formula[14].

Dynamic Muscular Strength

Dynamic muscular strength (kg) was determined with the one repetition maximum test (1RM) in the bench press and squat with free weight exercises. The procedures adopted for the test included five-minute general warm-up and specific warm-up. After each trial, the load value was redimensioned until the subjects were apt to perform only one repetition whose value was determined in the maximum of five trials. Interval between trials was of 4min, and performance velocity was of 2s for each phase (concentric and eccentric).

Resistance training sessions

As soon as the subjects arrived for the tests, they were positioned at dorsal decubitus and remained at rest for 10 minutes. They later seated and were equipped with a heart rate monitor and mask for gas collection attached to the gas analyzer (Medical Graphics, model CPX/D), remaining like this for extra five minutes. When the period of variables collection at rest ended, the individuals performed a set of 15 repetitions of warm-up to bench press and squat using a 10-kg barbell, starting immediately after the experimental session. During both sessions (LME and HP), all individuals performed first the bench press then squat. The exercises intensity was calculated from the 1RM values. The RE session was composed of three sets of each pair of exercises (bench press and squat), performed in alternation and with no interval between exercises and with one-minute interval between sets. The HP session comprehended performance of 6-8RM at 80% of 1RM intensity while the LME session comprehended performance of 15-20RM at 55% of 1RM intensity. During the exercises performance verbal encouragement was given to guarantee that all subjects performed the maximum repetitions within the set intervals. Immediately after the last exercise of the last set had been performed, the individual remained seated on a chair at rest during 10 minutes, and the data of the recovery period were then collected. The oxygen uptake ($\dot{V}O_2$), carbonic gas production (CO_2), ventilation (VE) and heart rate (HR) were continuously collected during the experimental sessions.

Determination of the time constant

In order to evaluate the kinetics of the $\dot{V}O_2$ recovery after resistance exercise performance, 1s interpolation was performed in the $\dot{V}O_2$.breath-by-breath data. Subsequently, a five-point moving mean was performed. The $\dot{V}O_2$ exponentially decreased after the end of the exercise. Thus, the $\dot{V}O_2$ time constant was determined by the adjustment of a monoexponential curve [15]. The general shape of this equation can be described as $\dot{V}O_2\ (t) = \dot{V}O_{2\ base} + \Delta \dot{V}\dot{V}O_2\ (e^{-t/\tau} - 1)$, where $\dot{V}O_2\ (t)$ is the $\dot{V}O_2$ in a t time, $\dot{V}O_{2\ base}$ is the rest $\dot{V}O_2$, $\Delta \dot{V}O_2$ is the response amplitude during recovery and τ is the time constant (TC). The TC was derived by non-linear regression using minimum squares through a computer program (Origin for Windows, Microcal Software, Inc., 2000). Determination

coefficient (r^2) and standard error (se) values were used as parameters to evaluate the monoexponential curve adjustment to the recovery $\dot{V}O_2$ data.

EPOC determination

The EPOC was determined through the calculation of the adjustment area of the monoexponential curve obtained from the recovery $\dot{V}O_2$ data plotted against the time. The rest $\dot{V}O_2$ values were used as base line of the calculation of the area and were calculated by the $\dot{V}O_2$ mean obtained in the last three minutes of rest.

Energetic cost determination

The recovery energetic cost was calculated based on respiratory exchange rate (RER) values higher than 1, since these values were observed in all individuals during the entire recovery period of the two experimental sessions (HP and LME). According to Scott[16-18], a RER > 1 during the recovery period indicates high rate of blood lactate oxidation, being necessary hence the use of 4.686kcal as calculation parameter of the energetic cost for each liter of oxygen consumed.

Statistical procedures

Descriptive statistics was performed for all variables (mean ± SD). T test for dependent sample was used for the comparisons between the different exercise sessions. Pearson linear correlation product moment tests were performed with the aim to verify associations between variables. The significance level adopted was of $p \leq 0.05$. All tests were performed in the SPSS, version 11.0 statistical program.

RESULTS

In our study, significant difference has not been found in the rest $\dot{V}O_2$ values in the pre-exercise situations between the two sessions ($p = 0.96$), indicating hence that the individuals left from a similar metabolic condition in both experimental sessions (316 ± 36ml/min for HP and 317 ± 37ml/min for LME). Exercise time was significantly higher for the LME session compared to the HP session ($p < 0.001$), the same fact occurring to the toning, where the LME values were significantly higher ($p < 0.001$) (table 2).

Table 2. Time of exercise (min), tonnage (kg x repetitions) and tonnage by time ratio (TON/MIN) of the resistance exercise sessions with emphasis on hypertrophy (HP), local muscular endurance (LME) and total (HP + LME).

Characteristics	HP session	LME session	P
Time of exercise	3:58 ± 0:34	5:50 ± 0:33	<0.001*
Bench press tonnage	1.112 ± 265.3	1.928.3 ± 359.9	<0.001*
Squat tonnage	2.016.6 ± 244.9	3.600 ± 389.7	<0.001*
Total tonnage	3.128.6 ± 434.5	5.555 ± 617.3	<0.001*
TON/MIN	787.3 ± 158.3	947 ± 130.5	<0.008*

Recovery period

The $\dot{V}O_2$ data processing collected during recovery presented mean determination coefficient for an exponential function of 0.93 ± 0.02 for the HP session and 0.95 ± 0.03 for the LME session. The mean standard error of theses curves was of 1.28 ± 0.35 for HP and 1.05 ± 0.29 for LME. Significant differences have not been found in the EPOC values (figure 1) and EC in the 10 minutes of recovery after the different RE sessions. Concerning the $\dot{V}O_2$ behavior kinetics variables in the recovery period, significant differences have not been found either between the TC values for the HP and LME sessions. However, differences between the $\dot{V}O_2$ means evaluated in the last minute of recovery with the rest $\dot{V}O_2$ values, both for the HP session ($p = 0.01$) and for the LME session ($p = 0.001$)were found . At the end of the recovery period it was observed that all individuals, regardless of the experimental session, presented respiratory exchange ratio (ERE) higher than 1.0 at the end of the 10 minutes of recovery (figure 2).

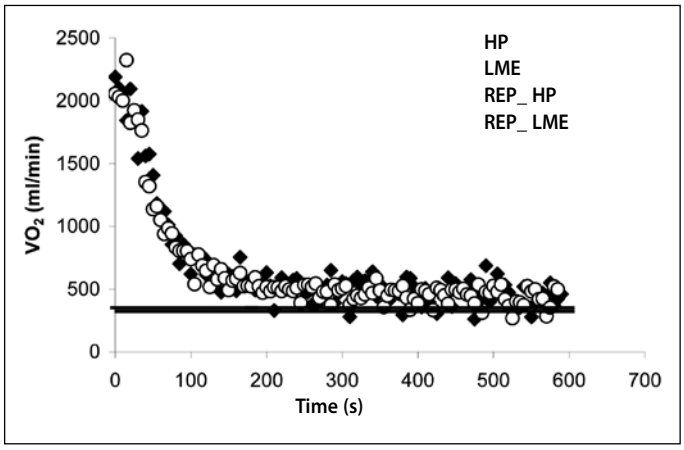

Figure 1. Oxygen consumption ($\dot{V}O_2$ ml/min) during 10min of recovery after training session for hypertrophy (HP) and local muscular endurance (LME). Rest values (RP) collected before the performance of each experimental session (REP_HP and REP_LME), are in evidence.

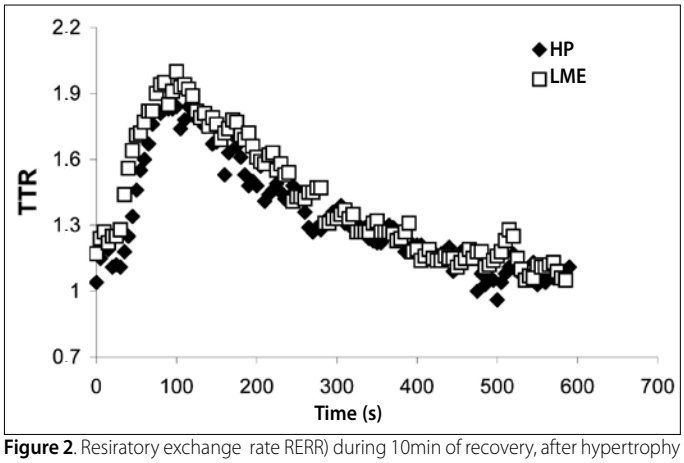

Figure 2. Resiratory exchange rate RERR) during 10min of recovery, after hypertrophy training session (HP) and local muscular endurance session (LME).

The total toning, exercise time and TON/MIN variables demonstrated low correlations with the TC, EPOC, EC and $\dot{V}O_2$_10min, with significance level of $p > 0.05$ for all of them, indicating that increase in the total work or exercise time did not necessarily cause increase in the TC, EPOC, EC and $\dot{V}O_2$_10min of recovery values. The highest correlation value found for total tonnage was of $r = 0.66$ (TC of LME), for exercise time was of $r = 0.61$ (TC of LME) and for TON/MIN was of $r = -0.59$ ($\dot{V}O_2$_10min of HP).

DISCUSSION

The main results of this study were the high EPOC and EC values compared to the rest levels, both in response to the RE training of LME and HP session, not demonstrating significant differences between these values. Such fact reveals that the RE

sessions were able to cause in the same way important metabolic disorders, and needed to consume during the recovery period energy amount higher than the rest levels to reestablish the metabolism homeostasis.

EPOC is influenced by all the factors responsible for the alteration of the mitochondrial respiration, since the mitochondrium represents the site of oxygen consumption in the cell [1]. However, the CP resynthesis kinetics as well as the intramitochondrial levels of ADP are the ones which present higher relation with the EPOC curve[19]. Many processes occur in the recovery period due to the wearing caused by exercise, and are responsible for great part of the alterations mentioned above, the more relevant being the reestablishment of the muscular ATP and CP supplies, the replacement of the hemo and myoglobinular oxygen supplies, the decrease of the sodium-potassium bomb activity and ion redistribution, blood lactate oxidation and glycogen resynthesis [4,10].

The literature shows that the intensity plays greater influence on the EPOC among the factors related to exercise. In a study by Poehlman[7], it was demonstrated in aerobic exercise that the higher the exercise intensity, the higher the EPOC response. Treuth *et al*.[3] demonstrated that 22% more of energy are necessary to perform the same amount of work in high intensity bicycle than in low intensity, even if the time of performance is higher for the low intensity. In another study, Burleson *et al*.[10] demonstrated that increase in the exercise duration result in linear increase of recovery EC, while increase in intensity causes exponential increase of this variable.

As previously mentioned, it is a consensus in the literature to classify the RE session with LME aim of low intensity, since it comprehends performance of a large number of repetitions at low percentage of maximum load; on the other hand, sessions with aim of HP are composed of low number of repetitions and high percentage of maximum load, considered hence, of high intensity [12,20]. Therefore, the LME session of the present study is classified as low intensity while the HP session represents high intensity. Despite having been of different intensities, the EPOC and EC values in the period of 10 minutes of recovery were similar for both protocols. Additionally, the TC values in response to the high intensity session in comparison to the low intensity session were similar, and significant differences were not found in the rate of $\dot{V}O_2$ decrease in the EPOC curves. Moreover, the adjustment of the curve for recovery $\dot{V}O_2$ data presented mean determination coefficient (r^2) similar for the two situations, which supports even more the Idea that the two sessions cause similar effects in the recovery $\dot{V}O_2$ behavior.

In studies by Olds and Abernathy[8] using sets of different intensities, but of same tonnage, no significant differences were observed in the EPOC between the high intensity session (12 repetitions at 75% of 1RM) and low intensity session (15 repetitions at 60% of 1RM). The absence of differences in the EPOC values could be attributed to the small difference between the intensities and number of repetitions of the sessions. Following the same proposal of the authors above, Thornton and Potteiger[4], comparing a high intensity set (2 x 8 at 85% of 8RM) with a low intensity set (2 x 15 at 45% of 8RM) with equal total work, found out results which point to significantly higher EPOC values in response to the high intensity session. Elliot *et al*.[9] compared the EPOC in response to three distinct exercise sessions, one high RE session (3 x 8RM at 80% of 1RM), and low intensity session (4 x 15 repetitions at 50% of 1RM), besides one session of continuous exercise in bicycle (27min at 45% of $\dot{V}O_{2max}$). Despite not controlling the total work volume in the continuous aerobic exercise, Elliot *et al*.[9] demonstrated that the session with higher total work resulted in higher EPOC, in this case, the high intensity session.

The main similarity of the studies mentioned above [4,8,9] is that all of them performed the low intensity session (e.g. LME) in an underestimated way, that is to say, the volume and intensity stimuli were lower than the ones indicated for gain in LME[13,20]. Thornton and Potteiger[4] performed the low intensity session (LME) at 45% of 8RMs, which equals to approximately 35% of 1RM, a value below recommendation [11]. Elliot *et al*.[9], despite working at 50% of 1RM, a suitable intensity for LME gain, limited the number of repetitions in 15, not following the proposal previously suggested of maximum repetitions [11,13]. Possibly, the underestimated volume may have caused the EPOC values always lower for the LME situation.

In the study by Thornton and Potteiger[4], the differences verified in the EPOC total value between the two RE intensities were attributed to the fast phase of the recovery curve. The authors verified that, regardless of the performed intensity, the $\dot{V}O_2$ values became similar to the pre-exercise values after 5min of recovery. Therefore, despite having performed a an evaluation fairly long of the recovery period (50min), the contribution of the fast phase on the total EPOC behavior was significant, since significant differences have been found between the EPOC of the two intensities. Thus, the authors believe that, among the main physiological aspects involved with the $\dot{V}O_2$ behavior during recovery, the factors involved with the alactic metabolism provided the differences verified between the resistance training sessions. However, the same conclusions cannot be applied to the present study. Although the contribution of the fast phase is equally important in the determination of the EPOC total value in the present study, it is not possible to state that the alactic factors had greater contribution in the EPOC response during recovery, since the total recovery period evaluated was of 10 minutes. This fact may have contributed to the increase of the importance of the fast phase in the EPOC calculation. In our study, the $\dot{V}O_2$ values during the slow phase of recovery remained significantly high for longer than the values of the slow phase of $\dot{V}O_2$ observed in the studies by Thornton and Potteiger[4] both concerning the high intensity session and ($\dot{V}O_2$REP: 316.6 ± 36.8l x $\dot{V}O_2$_10min:361.3 ± 36.4ml$_*$min^{-1}, p = 0.01) and the low intensity session ($\dot{V}O_2$REP: 317 ± 37.1l x $\dot{V}O_2$_10min:384 ± 35lml$_*$min^{-1}, p = 0.01). It means that the importance of the slow phase of the $\dot{V}O_2$ recovery curve in our study was higher than those observed by the authors in the 10 initial min of recovery.

Table 3. Post-exercise responses of the time constant of $\dot{V}O_2$ (s), EPOC (l), energetic cost (kcal) and $\dot{V}O_2$ mean variables in the last minute of recovery ($\dot{V}O_2$_10min: ml/min) assessed during 10 minutes of recovery and rest O_2 (O_2REP: ml/min) values for the hypertrophy (HP) and local muscular endurance sessions (LME).

Variable	HP session	LME session	p
TC	56.37 ± 7.56	57.73 ± 6.87	0.64
EPOC	2.21 ± 0.54	2.60 ± 0.44	0.14
EC	10.36 ± 2.53	12.18 ± 2.04	0.14
VO_2_10min	361.3 ± 36.4[a]	384 ± 35[a]	0.15
VO_2REP	316.6 ± 36.8[b]	317.4 ± 37.1[b]	0.39

Different letters mean statistically significant differences (p ≤ 0.01).

The existing differences in the slow phase between the two types of RE could provide differences in the total EPOC calculation. A datum which suggests a possible existence of differences in the EPOC values, in case the slow phase was evaluated for longer time, is the similarity of the recovery $\dot{V}O_2$ kinetics. The HP and LME sessions presented the same decline rate of $\dot{V}O_2$ (56.4 ± 7.6 vs. 57.7 ± 6.9s, respectively) in the first seconds of recovery, which is against the results by Thornton and Potteiger[4], who suggested that the difference between he EPOC of the RE sessions was the $\dot{V}O_2$ behavior in the fast phase, which suggests that, a possible difference in the EPOC between the RE sessions in a longer collection, such results would be attributed to the existing differences of $\dot{V}O_2$ in the slow phase.

Another aspect which makes the importance of the alactic components in the $\dot{V}O_2$ response relative during recovery is the respiratory exchange rate (RER) response. In the present study, these values remained higher than 1.0 during the 10 minutes of recovery. This factor indicates greater participation of the lactic metabolism during the exercise performance, since the high levels of blood lactate produced increase in the expired carbonic gas (CO_2) volume during recovery as a way of normalizing the acid-base balance. Although we have not performed a comparison test, the RER behavior seems to present similar behavior during recovery of the two RE sessions. This aspect suggests that the levels of blood lactate during recovery of the two RE sessions could not present important differences, despite the differences in intensity between sessions. The lactate oxidation after exercise is responsible for remarkable increase of recovery $\dot{V}O_2$, greatly influencing on the EPOC magnitude [1]. It is widely reported in the literature that both LME and HP sessions are responsible for the production of great amount of lactate [20,21]. Therefore, the high values of respiratory exchange rate persistent at the end of the 10 recovery minutes of both sessions suggest presence of high concentrations of lactate in the end of the exercise. Thus, it could have influenced on the similar EPOC of the two protocols of this investigation.

The data of the present study present a medium recovery EC, for a period of only 10min, of 10.3kcal (±2.5kcal) after the HP session and time of exercise of 3:58 ± 0:34min and 12.2kcal (±2.0kcal) after the LME session with exercise time of 5:50 ± 0:33min, with no significant difference between the EC of the two sessions ($p = 0.14$). Considering that the physiological disorder of an exercise time of approximately 5min (0.35% of 24 hours) was able to cause recovery EC of 12kcal in only 10min, these values seem "substantial" and of considerable impact in the energetic balance of the subjects, considering that in a monthly periodization of three sessions this recovery EC would sum 144kcal, value close to that of a RE session in circuit recommended to decrease of fat mass (losing weight) which is in mean 130.6kcal (±34.5kcal)[22].

FINAL CONSIDERATIONS

In conclusion, the HP and LME sessions produced similar EPOC, recovery EC and TC responses in young adult men untrained in RE. These results call attention that a resistance exercise session with aim of LME, considered low intensity, when performed at 100% of physical capacity (performance of RM in each set) can result in the same magnitude of response of metabolic parameters of a session considered high intensity. This fact questions the validity of prescription of resistance exercise intensity by the 1RM percentage concerning the metabolic variables which should be observed during recovery.

All authors have declared there is not any potential conflict on interests concerning this article.

REFERENCES

1. Gaesser GA, Brooks GA. Metabolic bases of excess post-execise oxygen consumption: a review. Med Sci Sports Exerc. 1984;16:29-43.
2. Melby CL, Tincknell T, Schmidt W. Energy expenditure following a bout of non steady state resistance exercise. J Sports Med Phys Fitness. 1992;32:128-35.
3. Treuth MS, Hunter GR, Williams M. Effects of exercise intensity on 24h energy expenditure and substrate oxidation. Med Sci Sports Exerc. 1996;28:1138-43.
4. Thornton MK, Potteiger JA. Effects of resistance exercise bouts of different intensities but equal work on EPOC. Med Sci Sports Exerc. 2002;34:715-22.
5. Hunter GR, Weinsier RL, Bamman MM, Larson DE. A role for high intensity exercise on energy balance and weight control. Int J Obes. 1998;22:489-93.
6. Meirelles CM, Gomes PSC. Efeitos agudos da atividade contra-resistência sobre o gasto energético: revisando o impacto das principais variáveis. Rev Bras Med Esporte. 2004;10:122-30.
7. Poehlman ET. A review: exercise and its influence on resting energy metabolism in man. Med Sci Sports Exerc. 1989;21:515-25.
8. Olds TS, Abernathy PJ. Postexercise oxygen consumption following heavy and light resistance exercise. J Strength Cond Res. 1993;7:147-52.
9. Elliot DL, Goldberg L, Kuehl KS. Effect of resistance training on excess postexercise oxygen consumption. J Appl Sport Sci Res. 1992;6:77-81.
10. Burleson MA, O'bryant HS, Stone MH, Collins MA, Triplett-Mcbride T. Effect of weight training exercise and treadmill exercise on post exercise oxygen consumption. Med Sci Sports Exerc. 1998;30:518-22.
11. Campos GER, Luecke TJ, Wendeln HK, Toma K, Hagerman FC, Murray TF, *et al*. Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones. Eur J Appl Physiol. 2002;88:50-60.
12. Häkkinen K, Pakarinen A. Acute hormonal responses to two different fatiguing heavy-resistance protocols in male athletes. J Appl Physiol. 1993;74:882-7.
13. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. Brit J Nutr. 1978;40:497-504.
14. Heyward VH, Stolarczyc LM. Avaliação da composição corporal aplicada. 1st rev. Ed. São Paulo: Manole, 2001.
15. Okamoto T, Kanazawa H, Hirata K, Yoshikawa J. Evaluation of oxygen uptake kinetics and oxygen kinetics of peripheral skeletal muscle during recovery from exercise in patients with chronic obstructive pulmonary disease. Clin Physiol Funct Imaging. 2003;23:257-62.
16. Scott CB. Energy expenditure of heavy to severe exercise and recovery. J Theor Biol. 2000;207:293-7.
17. Scott CB. Interpreting energy expenditure for anaerobic exercise and recovery: an anaerobic hypothesis. J Sports Med Phys Fitness. 1997; 37:18-23.
18. Scott, CB. Re-interpreting anaerobic metabolism: an argument for the application of both anaerobic glycolysis and excess post-exercise oxygen consumption (EPOC) as independent sources of energy expenditure. Eur J Appl Physiol. 1998;77:200-5.
19. Kenny GP, Niedre PC. The effect of exercise intensity on the post-exercise esophafeal temperature response. Eur J Appl Physiol. 2002;86:342-6.
20. Smilios I, Pilianidis T, Karamouzis M, Tokmakidis S. Hormonal responses after various resistance exercise protocols. Med Sci Sports Exerc. 2003;35:644-54.
21. Kraemer WJ, Patton JF, Gordon SE, Harman EA, Deschenes MR, Reynolds K, *et al*. Compatibility of high-intensity strength and endurance training on hormonal and skeletal muscle adaptations. J Appl Physiol. 1995;78:976-89.
22. Wilmore JH, Parr RB, Girandola RN, Ward P, Vodak P, Barstow TJ, ***et al***. Physiological alterations consequent to circuit weight training. Med Sci Sports Exerc. 1978;10:79-84.