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Effect of different resistance exercise repetition velocities on excess post-exercise oxygen consumption and energetic expenditure

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Abstract

Background: The excess post-exercise oxygen consumption (EPOC) consists of the excess oxygen consumed above a resting state following exercise. Performance of resistance exercise can significantly disrupt the body's homeostasis, with the EPOC being dependent on the specific combination of prescriptive variables. Presently, the effects of different repetition velocities on VO_2 and caloric expenditure during and following resistance exercise bouts have not been completely elucidated. **Objective:** To examine the effect of different repetition velocities on EPOC and total energetic expenditure during and following resistance exercise bouts. **Methods:** Twenty women (34.6 ± 5.5 years; 159 ± 4.1 cm; 55.1 ± 3.4 kg; 24±2.5 kg/m^{-2}; 18.9 ± 4.3 % body fat) performed two resistance exercise bouts that differed only in the velocity of repetitions: sequence 1 (SEQ1) involved 1 second concentric and eccentric phases and sequence 2 (SEQ2) involved 2 second concentric and eccentric phases. Both bouts utilized a 70% of 1-RM load for all exercises, performed for 3 sets of 10 repetitions. The respired gas analysis was assessed before, during, and for 60 minutes following each bout. **Results:** None of the variables assessed (i.e. VO_2, VCO_2, VE/VO_2, $VE/\ VCO_2$, V_E, RQ) were significantly different between bouts ($p > 0.05$). **Conclusion:** A relatively slower repetition velocity will produce similar energy expenditure during and following resistance exercise as a relatively faster repetition velocity, as long as the total volume is equal between resistance exercise bouts.

Keywords: resistance training; contraction, performance

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Introduction

Increasing energy expenditure through physical activity is one of the main objectives of weight loss programs. To effectively address this objective, the analysis of oxygen intake can be a powerful tool to estimate the energy expenditure associated with different physical activities[1,2]. The excess post-exercise oxygen consumption (EPOC) consists of the excess oxygen consumed in litres or ml/kg above a resting state following exercise. EPOC is reflective of the recovery demand and disruption of body's homeostasis in response to the physical stress imposed by exercise[3].

Performance of resistance exercise can significantly disrupt the body's homeostasis, with the EPOC being dependent on the specific combination of prescriptive variables. Some examples of prescriptive variables for resistance exercise includes: intensity (i.e. %1-RM), volume (i.e. load x sets x repetitions), rest interval between sets, mode, and repetition velocity. There are infinite possibilities in how these prescriptive variables might be combined to influence energy expenditure and oxygen consumption during and following a resistance exercise bout[4]**.** A previous study found that the respiratory exchange ratio was reduced in young men after a resistance exercise bout, suggesting an increase in lipid oxidation to meet energy demands[5].

Other studies that measured EPOC demonstrated a positive association between resistance exercise intensity (e.g. % 1-RM) and EPOC in resistance-trained women[1,6,7]. To these authors' knowledge, three studies have specifically compared different resistance exercise intensities and repetition velocities on energy expenditure, but none have compared with female[8,9,10].

Presently, the effect of different repetition velocities on VO_2 and caloric expenditure during and following resistance exercise has not been completely elucidated. Thus it would be useful, for exercise prescription purposes; to determine whether moving the resistance relatively faster or slower enhances caloric expenditure. Hence the purpose of the current study was to examine the effect of different repetition velocities on EPOC and total energy expenditure during and following resistance exercise.

Methods

Subjects

Twenty women (34.6 ± 5.5 years; 159 ± 4.1 cm; 55.1 ± 3.4 kg; 24±2.5 kg/m^{-2}; 18.9 ± 4.3% body fat) with at least two years of recreational resistance training experience were asked to participate in the current study. All subjects answered the Physical Activity Readiness Questionnaire - PAR-Q[11], IPAQ[12] and signed an informed consent according to the Declaration of Helsinki. The experimental procedures were approved by the Ethics Committee of the Universidade Federal do Rio de Janeiro. The following additional exclusion criteria were adopted: a) use of drugs that could affect the cardiorespiratory responses; b) bone-, joint- or muscle-diagnosed problems that could limit the execution of the resistance exercises; c) systemic hypertension (≥ 140/90 mmHg or use of antihypertensive medication); d) metabolic disease.

Body weight was measured to the nearest 0.1 kg using a calibrated physician's beam scale (model 31, Filizola, São Paulo, Brazil), with the men dressed in shorts. Height was determined without shoes to the nearest 0.1 cm using a stadiometer (model 31, Filizola) after a voluntary deep inspiration. Body-mass index (BMI) was calculated as body weight divided by height squared (kg/m^{-2}). Body fat percentage (%) was estimated using the seven-site skinfold procedures according to the guidelines of the American College of Sports Medicine[13].

1-RM testing and resistance exercise bouts

The 1-RM tests were assessed during two non-consecutive days in the same exercise order: lat pull down (LPD), squat in the Smith machine (SQ), triceps pulley (TP), lunges in the Smith machine (LG), seated shoulder press (SP) and biceps curl (BC). All machine exercises were performed on Life Fitness equipment (Franklin Park, IL). The 1-RM tests were performed following the anthropometric measurements on the first day. After 48h, the 1-RM tests were repeated to determine test–retest reliability. The heaviest load achieved on either of the test days was considered the 1-RM. The1-RM loads were determined in fewer than five attempts with a rest interval of five minutes between attempts and 10 minutes between different exercises.

The 1-RM testing protocol has been described previously and for reliability, the following strategies were adopted: (a) standardised instructions concerning the testing procedures were given to subjects prior to the test; (b) subjects received standardized instructions concerning exercise technique; (c) verbal encouragement was provided during the tests; e) the mass of all weights and bars was determined using a precision scale.

To investigate the effect of two different repetition velocities on oxygen consumption during and after resistance exercise, each subject performed two bouts separated by 48 hours in a randomised counter-balanced cross-over design. The bouts were designed with the same exercise order as the 1-RM testing described previously. The bouts differed only in the velocity of repetitions: sequence 1 (SEQ1) involved 1 second concentric and eccentric phases and sequence 2 (SEQ2) involved 2 second concentric and eccentric phases. Both bouts utilised a 70% of 1-RM load for all exercises, performed for 3 sets of 10 repetitions with 30 seconds rest between sets and 1 minute rest between exercises. Each bout was conducted in a circuit format (one set of each exercise was performed in sequence, progressing through the circuit three times). To control the repetition velocity, a metronome (Casio, Tokyo, Japan) was utilised during each bout.

Respired gas analysis

The VO_2 mask and equipment were fastened to the subject after being positioned for the first exercise. A face mask (Hans Rudolph V Mask™) covered the mouth and nose and was attached to a bi-directional digital flowmeter and fastened to the subject with a mesh hairnet and Velcro straps. The respired gas analysis began by assessing the subject at rest for 5 minutes with the VO-2000™ (Medical Graphics, Saint Louis*, USA)*. To establish a resting state, the following variables were considered: resting VO_2 at 3.5 mL/kg/min^{-1}, minute ventilation (V_E) between 8 and 15L/min, and the respiratory quotient (RQ) between 0.75 and 0.85 [14].

Warm-up prior to each resistance exercise bout consisted of one set of 20 repetitions for the first exercise (i.e. LPD) with 30% of the 1-RM load. A 1-minute rest interval was allowed between the warm-up and the commencement of the assigned resistance exercise bout. Total energy cost in kilocalories was assessed during each bout and for 60 minutes following each bout with subjects in a seated position. Heart rate was continuously monitored (Polar Accurex Plus™, Kempele, Finland) and measurements of oxygen consumption (VO_2), carbon dioxide production (VCO_2), and V_E were assessed every three complete respiratory cycles. Ambient temperature and humidity were fixed respectively at 20-22°C. The Medical Graphics VO-2000™ system was calibrated prior to each individual test according to the manufacturer's guidelines. In the 24 hours prior to each bout, subjects were required to (a) avoid caffeine and other metabolic-altering supplements and/or drugs; (b) engage in no physical activity; (c) be well-hydrated with no changes in food consumption; and (d) be well-rested.

Statistical analysis

Data were expressed as the mean ± standard deviation (M ± SD). A two-way ANOVA was used to assess differences in oxygen consumption during and 60 minutes following each SEQ1 and SEQ2. Bonferroni's post hoc tests were used to partition significant main effects. A Student's t-test was used to assess differences in the total energy expenditure between bouts. The significance level was set at $p<0.05$. All statistical analyses were performed using Graphpad Prism, Version 5.0 (Graphpad Software Inc., San Diego, USA).

Results

No significant differences were found between SEQ1 and SEQ2 for any of the variables assessed during, and 60 minutes following each bout (see Figures 1- 4). Figure 1 summarises $VO_{2\,peak}$ (SEQ1 – 1.27±0.2 L/ min^{-1}; SEQ2 – 1.34±0.2 L/ min^{-1}), VCO_{2peak} (SEQ1 - 1.15±0.1 L/ min^{-1}; SEQ2 – 1.25±0.2 L/ min^{-1}), $VE/VO_{2\,peak}$ (SEQ1 – 34.01±9.5 L/ min^{-1}; SEQ2 – 33.91±7.7 L/ min^{-1}), and $VE/\,VCO_{2\,peak}$ (SEQ1 – 36.34±5.8 L/ min^{-1}; SEQ2 – 36.2±6.5 L/ min^{-1}).

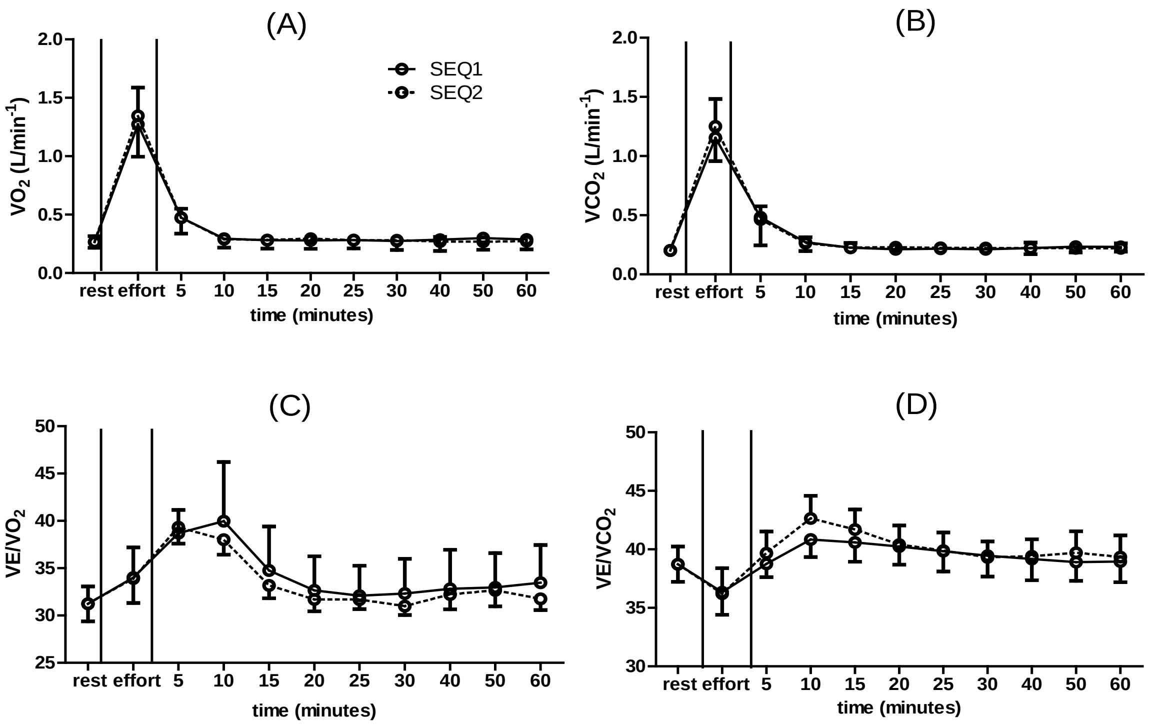

Figure 1: Mean respired gas analysis before, during, and 60 minutes following SEQ1 and SEQ2

Figures 2 and 3 summarise $V_{E\ peak}$ (SEQ1 - 41.78±8.3 L/ min^{-1}; SEQ2 – 45.02±10.1 L/ min^{-1}) and RQ (SEQ1 – 0.92±0.1 $Kcal.L^{-1}$; SEQ2 – 0.93±0.07 $Kcal.L^{-1}$).

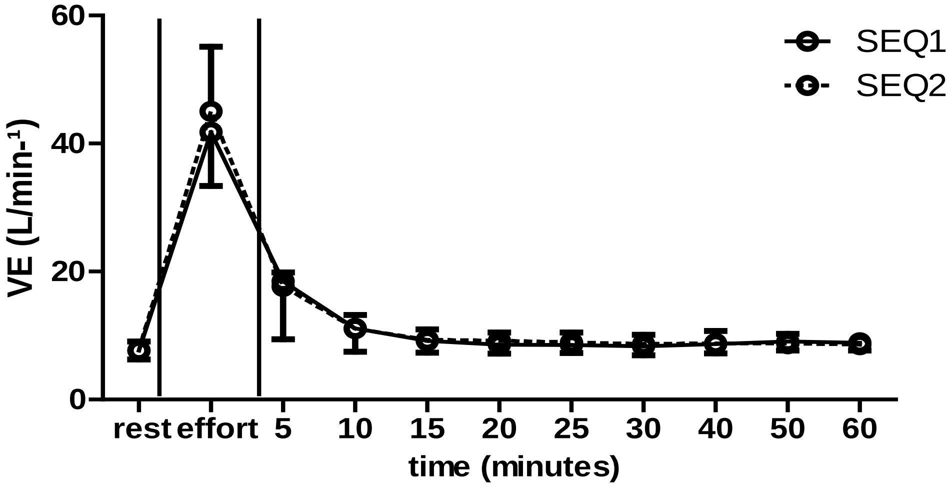

Figure 2: Mean minute ventilation (V_E) before, during, and 60 minutes following SEQ1 and SEQ2

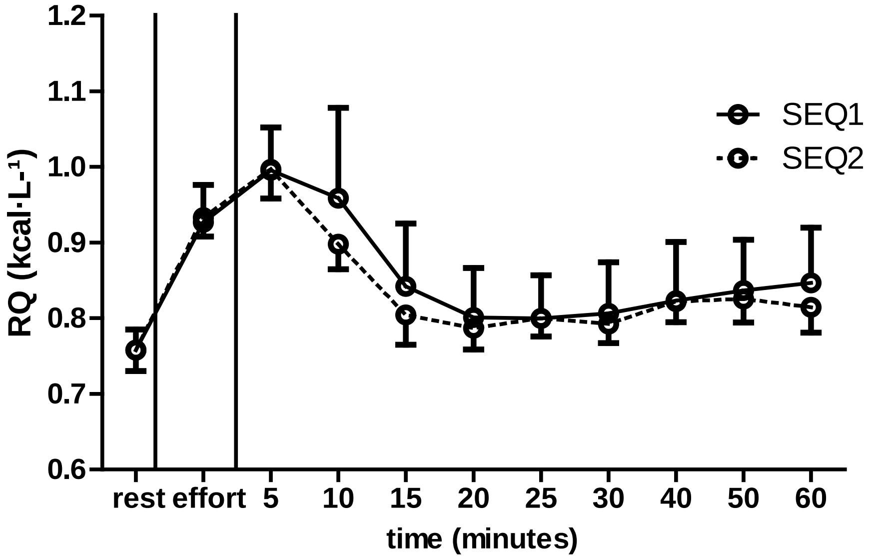

Figure 3: Mean respiratory quotient (RQ) before, during, and 60 minutes following SEQ1 and SEQ2

Figure 4 summarises total energy expenditure (SEQ1– 711.19 ± 86.33 Kcal.L^{-1}; SEQ2 – 728.73 ± 132.67 Kcal.L^{-1}).

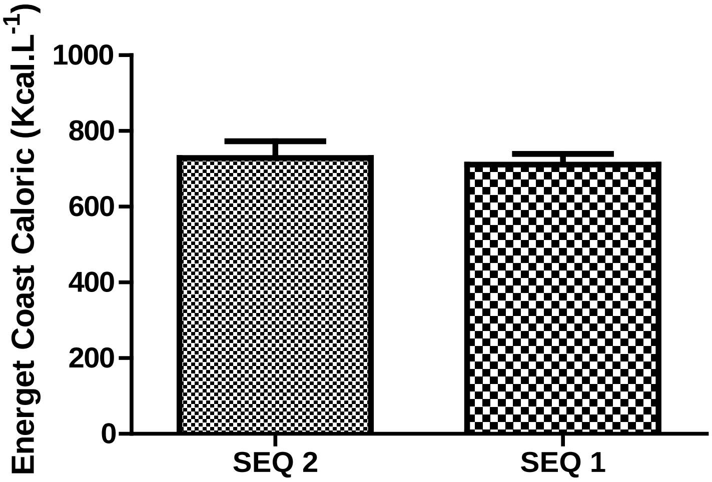

Figure 4: Mean total energy expenditure (kilocalories) before, during, and 60 minutes following SEQ1 and SEQ2

Discussion

The purpose of the current study was to examine the effect of different repetition velocities on EPOC and total energy expenditure during and following resistance exercise. The key finding was that VO_2 and total energy expenditure were not significantly different during and 60 minutes following each bout that involved different repetition velocities. There were also no differences between bouts in the total volume (load x sets x repetitions) performed; thus, this experiment was tightly controlled and bouts differed only in the velocity of repetitions.

The speed of muscle action has been shown to elicit different neural and the metabolic responses to resistance exercise. When lifting with maximal exertion, repetition velocity is inversely related to the relative load being lifted and follows the force/velocity curve [15]. However, when the intent is to purposefully move at a slower repetition velocity (often with a lower intensity load), the increased time under tension appears to be an important stimulus to elicit improvements in localized muscular endurance [16]**.** Ballor et al.[17] demonstrated that a slower repetition velocity during circuit training was more metabolically demanding versus moderate and faster repetition velocities. However, it is difficult to perform a large number of repetitions using a slower repetition velocity, which limits training volume. Consequently, it appears that both relatively fast and slow repetition velocities should be incorporated for improvements in localised muscular endurance.

Previous resistance training studies have demonstrated that faster repetition velocities with moderate to high loads were more effective versus traditional slower repetition velocities for absolute strength increase[8,9]. Thus, it appears that the intentional maximal acceleration of the load is critical for maximizing strength gains[18]**.** Although the resistance exercise bouts in the current study utilized a moderate load, the bout that utilized the faster repetition velocity did not elicit significantly greater increases in oxygen uptake. Perhaps there were insufficient differences in the repetition velocities studied (i.e. 1 second concentric/eccentric versus 2 second concentric/eccentric) for measurable differences.

Previous studies have demonstrated that the intensity (i.e. % 1-RM lifted) and explosive contractions is the main determinant of the oxygen uptake, EPOC and energy expenditure during and following resistance exercise bouts, with possible secondary importance on volume (sets x repetitions) [8,19]. In the current study, the bout duration of SEQ2 (2 second concentric/eccentric) was 26 minutes and the oxygen consumption was 157.07 L, while SEQ1 (1 second concentric/eccentric) was 20 minutes and the oxygen consumption was 138.10 L. There were no significant differences in the total volume completed for each bout, albeit slightly less total energy expenditure for SEQ1 versus SEQ2 (SEQ1 = 711.19 ± 86.33 $Kcal.L^{-1}$; SEQ2 = 728.73 ± 132.67 $Kcal.L^{-1}$). The results of the current study suggest that similar repetition velocities did not produce vastly difference responses when utilizing a moderate intensity load.

A few studies have examined EPOC following differently designed resistance exercise bouts[20,21]. These studies have demonstrated that resting metabolic rate (RMR) remained elevated for 48 hours after a moderate to high-intensity resistance exercise bout. The most pronounced level of EPOC, the rapid component, occurs for 1 hour following exercise and involves restorative physiological processes such as: restoration of muscle ATP and creatine phosphate stores; replenishment of O2 stores in the blood and muscles; redistribution of compartmental ions (increased sodium-potassium pump activity); reduction of heart rate and body temperature, and conversion lactate back to pyruvate [22]. In the current study, the reduction in the RQ following the bouts was consistent with the increase in O_2 consumption relative to CO_2 production during the recovery period [21]. The prolonged component of EPOC (beyond one hour), includes more prolonged restorative physiological processes such as: restoration of muscle glycogen stores and muscle tissue repair [23]**.**

Conclusions

The results of the current study suggest that when resistance exercise volume is equated between bouts, similar repetition velocities will produce a similar total exercise energy expenditure, albeit slightly greater energy expenditure for the slower repetition velocity due to longer bout duration. Such small differences may not be important in the short term, but the sum of small increases in total energy expenditure for repeated sessions over the long term (i.e. several months) could result in large accumulated energy expenditure and positively contribute to body mass control.

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