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ACUTE RESPONSES OF RATE PRESSURE PRODUCT IN SETS OF RESISTANCE EXERCISE

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Abstract

Objective: To compare the acute responses of rate pressure product (RPP) between dynamic and isometric sets of resistance exercise (RE); compare the acute responses of RPP between upper and lower limbs in RE.

Methods: Nineteen active men (22.7 ± 2.2 years) attended this study in a random crossover model. In the first day they performed hemodynamic measurements and one maximum repetition tests (1RM) in leg press (LGP) and bench press (BCP) exercises. In the second, third, fourth and fifth days they performed the following tests: LGP isometric, BCP isometric, LGP dynamic and BCP dynamic, respectively. Isometric protocols were conducted in 3 sets of 40 s (1st set: 25% 1RM, 2nd set: 50% 1RM, 3rd set: 75% 1RM) and dynamic protocols in 3 sets of 10 repetitions (1st set: 25% 1RM, 2nd set: 50% 1RM, 3th set: 75% 1RM). The RPP was obtained immediately after each set.

Results: A comparison between protocols showed that RPP was higher ($P < 0.05$) in dynamic than in isometric protocol. A comparison between exercises showed that RPP was higher ($P < 0.05$) in LGP than BCP exercise.

Conclusions: In similar relative intensities, the acute cardiac responses are influenced by the exercise protocol, since the RPP was higher in the dynamic condition. Furthermore, RPP seems to be related with recruited muscle mass, since that were observed higher values of RPP in exercises for lower limbs .

Key Words: *resistance training, muscle strength, heart rate, blood pressure*

Introduction

The relevance of physical exercises in the promotion of human health has been extensively described. In this sense, not only aerobic training but also resistance exercises (RE) have been suggested in sports medicine guidelines [1]. RE consists of exercises where multiple variables can be manipulated such as: Exercise order, rest periods between sets, specific exercises and session format, weekly frequency, movement velocity, training duration and volume, number of repetitions, sets, type of muscle action and intensity of effort can all be manipulated to meet the training goals and individual differences in training needs [2]. The prescription of RE is recommended for subjects of different ages and fitness levels and the advantages of RE include strength increases as well with cardiovascular improvements [1]. Thus, a well understanding of cardiovascular responses during RE may collaborate to the better control of hemodynamic parameters and finally facilitate the training prescription.

Cardiovascular response during RE are known to be directly related to the intensity of effort, duration and degree of active muscle mass recruited during exercise. During prescription of RE some physiological variables as heart rate (HR) and blood pressure should be monitored, particularly in populations with special care but, however the observation of these variables alone does not guarantee client safety [3-4]. On the other hand, the association between them may provide information that correlates with myocardial oxygen consumption, which is denominated rate-pressure product (RPP) and is calculated by multiplying systolic blood pressure (SBP) by HR [5-6]. Thus, RPP is a direct indication of the energy demand of the heart and thus a good measure of the energy consumption of the heart [7]. The magnitude of BP, HR, and RPP responses during RE are directly related to intensity of effort, the number of repetitions and sets, the rest interval, and time of muscle recruitment [2]. However, the RPP should be used for evaluation and prescription of exercise rather than HR or blood pressure alone [4].

The dynamic and isometric muscle actions can be included for cardiac rehabilitation and improvement of cardiovascular conditioning [8]. The dynamic protocols of RE produce increase of the heart rate and stroke volume. In parallel, a higher action of the skeletal muscle pump and decrements in peripheral vascular resistance increase the venous return to the heart. The isometric protocols of RE promote a significant pressure on the heart to increase perfusion to the active skeletal muscle [9]. Pollock et al. [8] comment that the RPP is lower during maximal isometric and dynamic resistance exercise than during maximal aerobic exercise, primarily because of a lower peak heart rate response. Thus, bearing in mind the importance to determine these aspects to promote greater control, efficacy and safety in conditions of practical application of resistance training the aims of the present study were to compare the acute responses of rate pressure product (RPP) between dynamic and isometric sets of RE as well as compare the acute responses of RPP between upper and lower limbs in RE.

Methods

Participants

Nineteen healthy male volunteers (age 22.8 ± 2.3 years, body mass 82.7 ± 15.4 kg, height 1.81 ± 9.5 m, body fat 11.6 ± 2.9 %) with at least one year of recreational resistance training experience were asked to participate in the current study. All subjects answered the Physical Activity Readiness Questionnaire - PAR-Q [10], IPAQ [11] and signed an informed consent according to the Declaration of Helsinki. The experimental procedures were approved by local Ethics Committee and were performed in accordance with the international ethical standards. 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; e) not take exogenous anabolic–androgenic steroids, drugs or medication with potential effects on physical performance.

All testing was performed between 1:00 and 3:00 PM. Subjects received a light lunch 2 hours before the test. Coffee, tea, alcohol and tobacco intake was prohibited for 48 hours, and subjects avoided formal and strenuous exercise for 48 hours before testing. Volunteers attended the laboratory seven times in the total with 48h between visits. For initial screening, at the start of the baseline week they performed anthropometric and hemodynamic measurements, and 1RM tests for Bench press (BCP) and Leg press (LGP) exercise. In the 2nd, 3rd, 4th and 5th visits they performed the following tests: LGP isometric, BCP isometric, LGP dynamic and BCP dynamic, respectively. In sequence, in the 6th and the 7th visits the volunteers did only LGP exercise isometric and dynamic, 3 sets with 75% of 1RM (see protocol exercises for details). Figure 1 illustrates the experimental design of study.

Measurements procedures

All evaluations were executed by the same experience researcher. Subjects were instructed about the tests, exercises techniques and the same equipment were used to complete the tests.

Protocol exercises

Isometric protocol consisted of 3 sets of 40s at an angle of ninety degrees at the knee and elbow for LGP and BCP, respectively. The dynamic protocol consisted of 3 sets of 10 repetitions. In both protocols (isometric and dynamic) loads of 25% (1st set), 50% (2nd set) and 75% (3th set) of 1RM were used, with 180 s of rest between sets. The subjects were encouraged not to hold their breath during the execution of exercises in order to minimize changes in HR and SBP.

Anthropometric and hemodynamic measurements

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 fat percentage (%) was estimated using the seven-site skinfold procedures according to the guidelines of the American College of Sports Medicine.

Blood pressure, both SBP and DBP, were measured at rest (at least 2 measurements on both arms after 10

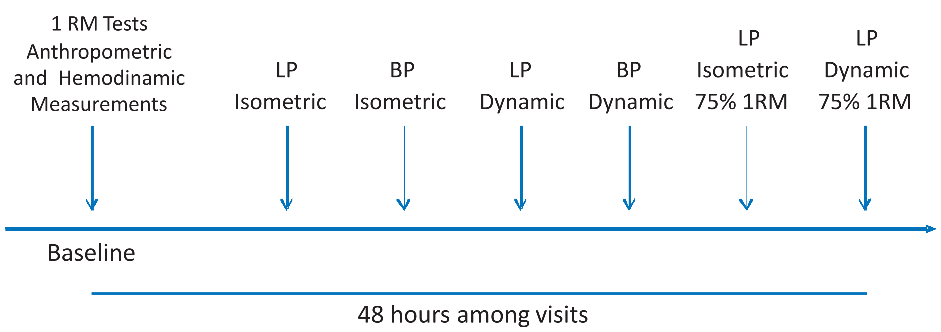


Fig. 1. *Experimental design of study*

minutes in the supine position) and immediately post each set of BCP and LGP exercise by a measure based on the 1st and 5th Kortokoff sounds, respectively, using a cuff specially adapted to the enlarged upper arm girth as needed. Blood pressure was measured on the left arm according to the auscultatory method with a mercury-column sphygmomanometer (auscultatory method, Vasquez-Lubry® sphygmomanometer-Germany, Littman stethoscope-USA). RPP was estimated by SBP x HR. The HR was obtained utilizing HR monitor (Polar® S810).

Maximal strength test for Bench Press and Leg Press Exercise (1RM - One-Repetition Maximum)

The 1RM testing was conducted using the methods described by Brown and Weir (2001). The subjects performed a general warm-up (3–5 minutes of light activity involving the muscles to be tested) and specific warm-up comprised of two set of ten repetitions, separated by a two-minute interval, with load of 50% body mass. After that, subjects performed a specific warm-up set of 8 repetitions at approximately 50% of the estimated 1RM, followed by another set of 3 repetitions at 70% of the estimated 1RM. Subsequent lifts were single repetitions of progressively heavier weights until the 1RM was determined to the desired level of precision. Rest intervals between each attempt to ensure phosphocreatine recovery were of approximately 4–5 minutes [12].

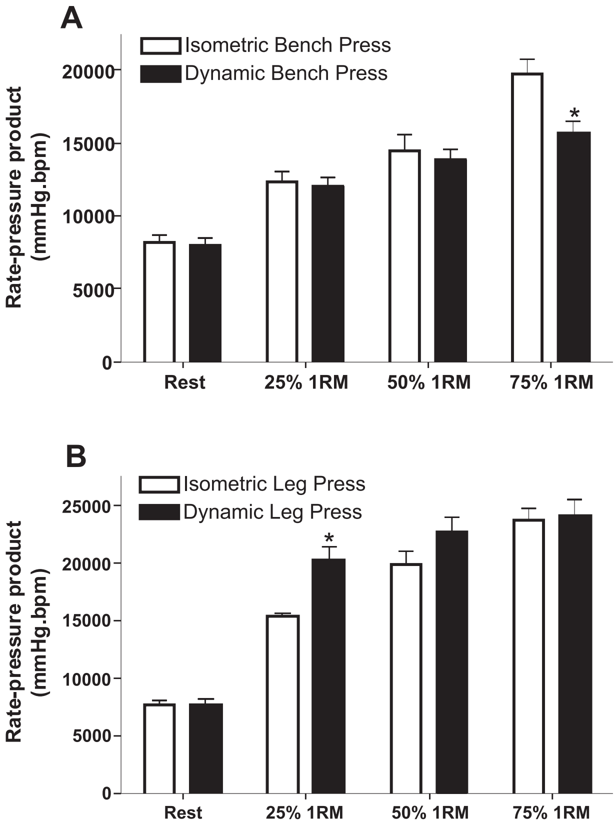
The 1RM testing protocol has been described previously and for reliability, the following strategies were adopted: (a) standardized instructions concerning the testing procedures were given to subjects prior to the test; (b) subjects received standardized instructions concerning exercise technique; (c)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

Statistical analysis

All data are expressed as mean ± standard error of the mean (SEM). A Shapiro-Wilk test was conducted to test the distribution of the data. For comparisons between isometric and dynamic exercise protocols, two-way analysis of variance (ANOVA) was applied, followed by Tukey's post hoc test. Statistical significance was established at the $P < 0.05$ level (GraphPad Software®, Inc.).

Results

No significant difference for RPP was found for set 1 (25% 1RM) and set 2 (50% 1RM) when comparing isometric and dynamic BCP exercise ($P > 0.05$). However, RPP was significantly higher immediately following the 3rd set (75% 1RM) for isometric compared to dynamic BCP exercise ($P < 0.05$) (Fig. 2A). For the same comparisons on LGP, RPP responses were significantly higher in dynamic compared to isometric



** significant difference between isometric and dynamic contractions (P < 0.05).*

Fig. 2. *Comparison between rate pressure responses at each set, after isometric (25%, 50%, 75% 1RM, 40s) and dynamic sets (25%, 50%, 75% 1RM, 10 repetitions). A, bench press exercise and B, leg press exercise. Data are expressed as mean ± SEM.*

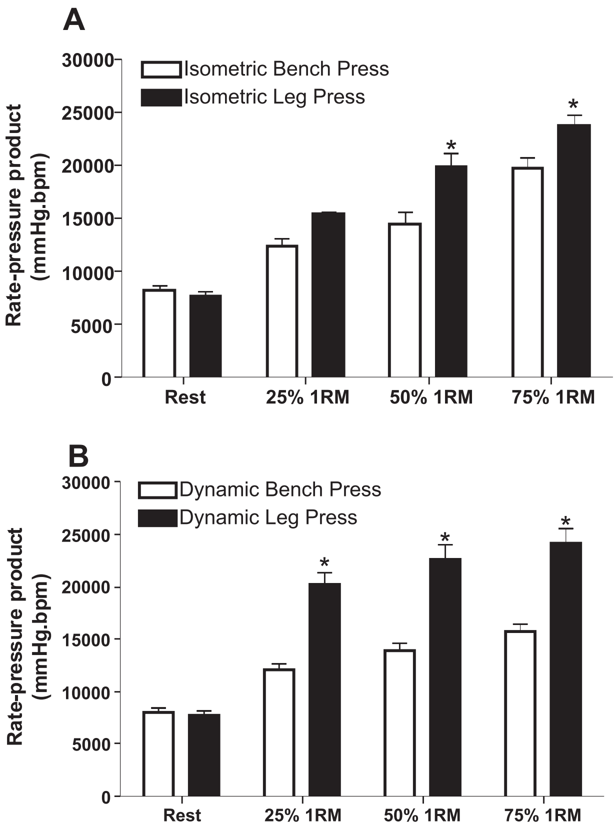


Fig. 3. *Comparison between rate pressure responses at each set, in Leg press vs Bench press. A, after isometric sets (25%, 50%, 75% 1RM, 40s) and B, after dynamic sets (25%, 50%, 75% 1RM, 10 repetitions). Data are expressed as mean ± SEM. *P < 0.05.*

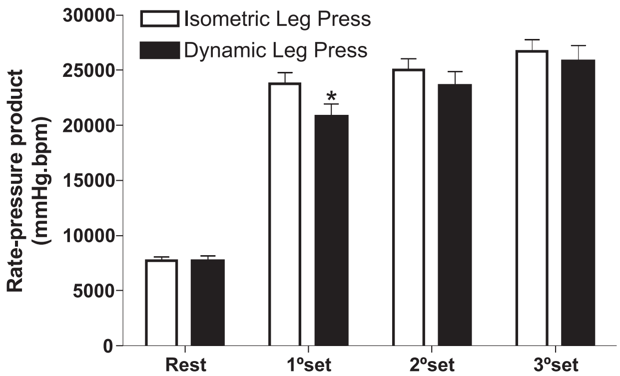


Fig. 4. *Comparison between RPP responses after each set of isometric and dynamic LP protocol. It was performed 3 isometric (75% 1RM, 40 s) and dynamic (75% 1RM, 10 repetitions) sets. Data are expressed as mean ± SEM. *P < 0.05.*

action for the 1st set ($P < 0.05$) but no difference was found after 2nd and 3rd set (Fig. 2B).

Figure 3 (A and B) shows the comparison between exercises (LGP vs BCP). For both isometric and dynamic situations, LGP responses were higher ($P < 0.05$) than BCP, for all but the 1st set of isometric testing (25% 1RM).

The Fig. 4 demonstrates the comparison between dynamic and isometric protocols with the same relative load (75% 1RM) in the 3rd sets, in LGP. There was no difference ($P > 0.05$) between isometric and dynamic LGP, except for the 1st set where isometric was higher than dynamic LGP ($P < 0.05$).

Discussion

The purpose of this study was to evaluate the acute cardiovascular responses after sets of dynamic and isometric strength exercise for lower and upper limbs in different intensity of effort. Our main finding is that the RPP was significantly higher in LGP in comparison to the BCP, in both dynamic and isometric protocols. This fact may be due muscle mass involved in the exercises, e.g. that the LGP activates greater muscle mass than the BCP [12]. The exercise intensity plays a role in the magnitude of HR increase being related to the recruited muscle mass, corroborating our findings [13]. Indeed, the change in vasomotor tone and not stroke volume seems to be the main modulator of the different blood pressure response observed during dynamic and isometric protocols [14].

The muscle mass recruited in the exercise is related with the increase in the blood pressure, especially due to compression of the vascular bed that blocks the circulation partially and consequently rise in the vascular resistance [15]. Furthermore, with the increase of the motor units recruited by exercise intensity, the cardiovascular adjust would be perceived by the mechanoreceptors that generate the recruitment of new motor units, since after the execution of a set, some of the muscle fibers are already fatigued. This response seems to be evoked by stimulation of groups III (mechanosensitive) and IV (metabosensitive) muscle afferents (according to the temperature, chemical and the mechanical environment) being favorable to a reflex increase in sympathetic nerve activity that promote a greater heart rate and arterial blood pressure [16-17]. The increased local muscle metabolites (H+, lactate, and ADP) and heat production seem to contribute for the increased heart rate responses after moderate and high intensity exercise [18].

In our study the progressive intensities used in both experimental dynamic and isometric protocols were determinant factor for the obtained results. This is potentially caused by a pressure load imposed on the cardiovascular system as a result of increased perfusion at the contracting skeletal muscle. However, in the resistance exercise prescription, the 25% 1RM load can be considered infeasible. Additionally, was found a cumulative effect of the sets in the RPP response, in both protocols (Dynamic and Isometric), with 75% 1RM in all three sets. Other study observed that the HR tended to increase with each set in succession, suggesting a cumulative effect of the sets [19]. This cumulative effect can promote adjustments by central mechanisms that increase impulses of the central motor cortex to the cardiovascular center that contribute to the blood pressure increase in high intensity exercise [20]. In previous studies the superimposition of an elevated intrathoracic pressure caused by a valsalva maneuver has been reported to contribute to an increased RPP [15]. The LGP exercise realized with isometric contraction promoted significant increase of RPP in the first set with 75% 1RM, may be by a rapid increase in both systolic pressure and diastolic pressure, which appears to be inappropriate for the amount of work produced by the contracting muscle.

A study limitation was the use of the auscultatory method to measure the arterial blood pressure. This technique tends to underestimate the absolute values during resistance exercises. However, using the auscultation method is possible to identify the relative cardiac overload caused by different exercises. In addition, the advantages include accessibility, cost, and non-invasiveness, and as such this method could be a useful tool for controlling intensity of effort with exercising participants.

Conclusion

In conclusion, the present results show that the absolute RPP responses on lower limbs are significantly higher than upper limbs, both dynamic and isometric protocols. In addition for lower limbs exercise, those responses are greater for dynamic compared to isometric protocol, while the same comparison for upper limbs shows higher responses for isometric compared to dynamic protocol. These findings provide valuable information for training prescription in different environments (clinical, amateur sports, high performance), since previous data in literature showed higher responses of RPP in isometric exercises. Furthermore, this suggests that future studies should investigate this issue again to establish increasingly precise situations of acute responses to resistance training.

Declaration of interest

The authors report no conflicts of interest.

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Authors' contribution
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection