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Acute Hemodynamic Responses in Resistance Exercise: Effect of Number of Sets

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[1]University Center – UniFMU, [2]São Judas Tadeu University-Department of Physical Education, São Paulo, São Paulo, Brazil, [3]University of Sao Paulo, Faculty of Pharmaceutical Sciences-Department of Experimental Nutrition, São Paulo, São Paulo, Brazil, [4]Department of Sport Sciences, Federal University of Triângulo Mineiro (UFTM), Uberaba, MG, Brazil, [5]University of São Paulo, Faculty of Public Health, São Paulo, São Paulo, Brazil, [6]Human Performance Research Group, Methodist University of Piracicaba (UNIMEP), Piracicaba, São Paulo, Brazil, [7]Faculty Adventist of Hortolândia (UNASP), Hortolândia. São Paulo, Brazil

ABSTRACT

Battazza RA, Neves FM, Evangelista AL, Bocalini DS, Junior AJF, Ribeiro HQ, Marocolo M, Costa EF, Mota GR, Moreno MA, Lopes CR. Acute Hemodynamic Responses in Resistance Exercise: Effect of Number of Sets. **JEPonline** 2014;17(2):53-59. This study analyzed the effect of resistance exercise sets on resting and exercise heart rate (HR), systolic blood pressure (SBP), and double product (RPP) in 10 trained women. The 6 months of resistance training consisted of 4 series of 10 repetition maximum (RM) using a horizontal leg-press exercise with 2 min of rest between bouts. A one way ANOVA and the *post hoc* Tuckey test (P≤0.05) were used to find statistical significance. The findings indicate that SBP, HR, and RPP responses were significantly increased from rest to exercise. Systolic blood pressure was significantly increased between the 3rd and 4th sets vs. the 1st set. The number of sets increased SBP, but only when more than 2 sets were performed. The time of execution of each set and the rest interval between the sets was not high enough to induce a significant increase in HR and RPP.

Key Words: Resistance Training, Hemodynamic Responses

INTRODUCTION

Physical exercise is characterized by physiological responses that help to promote an increase in the metabolic demand of the contracting muscles. In addition to the increase in respiratory function, there is an increase in cardiac output (Q) to help ensure an adequate supply of the inspired oxygen reaches the muscle tissues (1). The American College of Sports Medicine (2) suggests that beginner and intermediate healthy adults with an interest in strength or muscle gains or even in maintaining muscle size and strength should engage in resistance training (RT) defined as 8 to 12 repetitions of 1 to 3 sets using at least one exercise per main muscle group.

Subjects who are untrained but experienced in RT may train in cycles with 80 to 100% of 1 repetition maximum (RM) using multiple sets. For athletes who engage in RT with the expectation to improve their physical aptitude, the prescription in unique sets does not represent the best stimulus to cause adaptations in the neuromuscular response (3). In fact, several studies (4,5) indicate that the performance of multiple sets seems to be more effective in trained individuals. Fleck and Kraemer (6), in particular, state that the following criteria should be observed when engaged in a weight training program: (a) choice of exercises; (b) order of exercises; (c) duration of recovery periods; (d) intensity of the sets; and (e) number of sets. Among these variables, the number of sets is related to training volume, which depends on the goals proposed for the training program.

Among the adaptations related to RT, the cardiovascular responses appear to undergo important acute adjustments. This is true especially for heart rate (HR) response, systolic blood pressure (SBP), and rate-pressure product (RPP). This is true during RT as well as the recovery period (3). RPP is an important indication of cardiac efficiency. When it is increased, it is also important that the coronary arteries can supply an increase in blood flow and oxygen to the myocardium (MVO_2). The relationship between the RPP and MVO_2 can be better understood by reviewing the regression equation (MVO_2 = .14 (RPP) – 6.3). Hence, if RPP increases, then, MVO_2 increases as well (7). This is why RPP can be used to determine the cardiac overload associated with weight training programs (8,9).

During RT, the hemodynamic response of SBP suggests that successive use of sets during RT increases the work of the heart (10-12). In support of this connection between RT, successive sets, and SBP, Gotshall et al. (9) evaluated the effect of the number of RT sets on SBP, during which the subjects performed 3 sets of 10 repetitions with 3 min of rest between each set using the leg press exercise. They found that SBP was 238 ± 18 mmHg in the 1st set, 268 ± 18 mmHg in the 2nd set, and 293 ± 21 mmHg in the 3rd set. The evidence indicates a progressive increase in cardiovascular stress (particularly an increase in MVO_2) in relation to successive sets. The same response has been reported in other studies by Miranda et al. (13) and Miranda and colleagues (14).

Although many studies have shown hemodynamic responses related to resistance training in men, there are relatively few studies using women as subjects. Hence, the purpose of this study was to analyze the acute cardiovascular responses in healthy young women engaged in multiple sets of leg press exercise.

METHODS

Subjects

Ten healthy women with a mean age, body weight, and height of 24 ± 4 yrs, 55 ± 5 kg, and 166 ± 10 cm, respectively, and ~6 months of experience in RT were subjects in this study. None of the subjects used ergogenic aids to enhance athletic performance. None had problems with joints or muscles that might prevent execution of the exercises, and none were consuming substances (such as caffeine or

alcohol) that might alter HR and/or SBP responses at the time of data collection. The subjects were informed not to participate in physical activities 24 hrs prior to testing. All subjects signed a Free and Clarified Consent Term according to the resolution number 196/96 of Brazilian Healthy Council, which was approved by the Research Ethics Committee.

The subjects' HR was assessed via the use of a Polar Heart Rate Monitor (FS5 Model) while SBP was determined via a Solidor Sphygmomanometer and a Litmann Classical SE (USA) stethoscope. Rate pressure product (RPP) was calculated using the equation: (RPP = HR x SBP x .001).

Procedures

The subjects were engaged in the experimental procedure during 4 non-consecutive days. On the 1st day, in order to select the criteria-defined subjects, a PAR-Q questionnaire (15) and an anamnesis were applied. On the 2nd and 3rd days, a 10 RM test in the horizontal leg press apparatus was performed. On the 4th day, the subjects' hemodynamic responses (HR, SBP, and RPP) were recorded at rest and during the exercise conditions. All measurements were taken at the same time of day to avoid any influence of the circadian cycle.

Ten RM test

In order to select the correct load in the 10 RM test, a method of trial and error was adopted. It started with lower loads that were increased gradually until the subjects could not execute the 11th repetition, which corresponded to the end of the test. The 10 RM test was performed using a horizontal leg press machine, pushing the platform with 2 feet simultaneously. The interval between tests was 48 hrs. The purpose of the interval time was to determine the reproducibility of the loads. The load equivalent to 10 RM was determined during both days with a relative difference lower than 5%. The load was obtained in 4 trails maximum with an interval of 5 min between trials.

To reduce possible errors in the 10 RM test, the following strategies were adopted (16): (a) the standardized instructions were given before the test to ensure that the subjects were aware of the data collection procedures; (b) the execution technique of the exercise was explained; (c) the stages of execution for the initial position and development of execution (concentric and eccentric actions) were determined; and (d) a standardized verbal stimulus was used to keep the desired level of stimulation during the execution of the exercise.

Training Protocol

All subjects were submitted to the same training protocol, which involved 4 sets of 10 RM with a recovery interval of 2 min between sets. The exercise was performed on a horizontal leg press machine of which the subjects pushed the platform with both feet simultaneously. To execute the exercise, the subjects were seated with their feet symmetrically aligned to the iliac crest extension. In the beginning of each repetition, the knees and hips were flexed 90º. In the concentric phase, there was an extension of the knees and hips with a subsequent return to the initial position. The use of 4 sets was based on the findings of Rhea and colleagues (23) who reported positive gains of strength in both trained and non-trained subjects.

Collection of Cardiovascular Variables

During data collection, the subjects remained seated for 10 min in the resting state while HR, SBP, and RPP were determined. The subjects' HR was measured continuously at rest from which the lowest value was used. Systolic blood pressure was measured at the end of the 9th min. The subjects were told not to hold their breath to avoid interfering with the HR and SBP measurements. The assessment of SBP was performed using the auscultatory method at the 8th and 10th repetition of

each set, given that the higher values are often found during the two last repetitions of a set (17). The subjects' left arm was used.

Data Analysis

Statistical analysis was performed using a one way analysis of variance (ANOVA) followed by the *post hoc* Tukey test (P≤0.05). The software Biostatistic 5.0 was used to analyze the data.

RESULTS

The hemodynamic data are presented in Table 1. While there were statistical differences between the resting HR and the HR responses during each set, there were no differences among the HR values for each set. There was a significant difference SBP in all sets compared with the resting state. RPP was significantly lower than in all sets. However, there was not statistical difference when comparing one set versus another.

Table 1. Mean ± SD in Heart Rate, Systolic Blood Pressure, and Rate Pressure Product at Rest and During 4 Sets.

	REST	1st SET	2nd SET	3rd SET	4th SET
HR (beats·min^{-1})	73 ± 7.4 #	138 ± 17.4	136 ± 18.2	139 ± 17.8	140 ± 18.9
SBP (mmHg)	107 ± 6.8 #	126 ± 8.6 †	134 ± 9.4	142 ± 7.8	137 ± 8.6
RPP	7.8 ± .60 #	17.4 ± 2.8	18.3 ± 3.2	19.8 ± 3.3	19.3 ± 3.1

#Significant difference (P≤0.05) for rest vs. sets 1, 2, 3 and 4; †Significant difference (P≤0.05) for sets 3 and 4 vs. the 1st set.

DISCUSSION

It has been known for some time that significant changes take place in the subjects' hemodynamic responses when engaged in RT (14,18,19,20). Interestingly, while HR and SBP, in particular, are mediated by similar mechanisms (21), the acute behavior of each is often dependent upon such factors as the thermal response during the exercise, plasma volume, duration, and intensity of the sets (22). Leite and Farinatti (11) reported that when their subjects performed 12 RM in different exercises with the same muscle group, HR during the last 4 repetitions in each exercise tended to be higher than during the first 8. They reported that the HR result was related to the vasoconstrictor effect of the resistance exercise.

Another important factor related to the peak HR response during resistance exercise was the duration of the exercise stimulus (24). This observation was pointed out in a recent study by Miranda et al. (13). They showed that in bilateral knee extension the acute HR response was lower than when in the unilateral or alternating exercise pattern. This finding indicates that when a resistance exercise is performed with 2 legs at the same time the hemodynamic response is impaired (i.e., higher than it would be otherwise). However, the present study found that the HR responses for each set were not significantly different. The average HR response during the 4 sets was in the range of 138-140 beats·min^{-1}. Although this finding is in agreement with Leite and Farinatti (11), other studies disagree (3,11,13,14,25).

Compared to the 1st set, SBP was significantly higher after the 3rd and 4th sets. This finding was expected since the magnitude of the SBP response is directly related to the number of sets during the RT exercise (9,11,18). However, in regards the response of SBP in a continuous and discontinuous protocol, there were increased values in SBP in continuous effort and in the discontinuous work in the last series (14). Conversely, Monteiro et al. (15) did not show a progressive increase in SBP when higher quantities of sets were done. An increased SBP related to the number of sets may be explained by a higher effort caused by muscular recruitment. Execution of the Valsalva maneuver and tissue hypoxia may also play a role in the SBP response (9,10,20).

Evidence suggests the total time of RT exercise with the same workload is the primary factor that increases the work of the myocardium (9,10,22). Yet, in regards to RPP responses during the sets, it appears that the intensity of the effort might be more responsible for the changes in HR (that did not take place in this study) and the relatively small (but significant) changes in SBP (19).

Limitation

The primary limitation of this study is the measurement of SBP using the auscultatory method may have not produced the best measure of blood pressure during RT exercises. Yet, the method appears to have been an accurate assessment of SBP during RT in the study by Polito et al. **(18)**. In a general manner, there were similarities in regards to the SBP values among all sets, and these values are significantly higher than during resting, corroborating the study of Sale et al. (24).

CONCLUSIONS

The findings indicate that SBP, HR, and RPP responses were significantly increased from rest to exercise. Systolic blood pressure was significantly increased between the 3rd and 4th sets vs. the 1st set. The number of sets increased SBP, but only when more than 2 sets were performed. The time of execution of each set and the rest interval between the sets was not high enough to induce a significant increase in HR and RPP.

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