Original article

Cardiovascular response to strength training is more affected by intensity than volume in healthy subjects

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\section*{ABSTRACT}

Objective: To determine and compare the cardiovascular responses to three resistance exercise protocols with different volumes and loads.

Methods: The study included 15 healthy subjects, experienced in resistance training, who underwent supine bench press exercise with three different volumes and loads separated by 48 hours, with a crossover model: a) 4 repetitions at 90% of one repetition maximum (4/90%), b) 8 repetitions at 80% of one repetition maximum (8/80%), and c) 15 repetitions at 65% of one repetition maximum (15/65%). Immediately following each protocol, measures of heart rate, systolic and diastolic blood pressure were performed, and were used to calculate the rate pressure product.

Results: The 4/90% protocol resulted in an increase in heart rate ($\Delta = 84.57\%$); effect size [ES] = 0.31), systolic blood pressure ($\Delta = 24.03\%$; ES = 0.42), diastolic blood pressure ($\Delta = 8.47\%$; ES = 0.27) and rate pressure product ($\Delta = 129.65\%$; ES = 0.54). The 8/80% protocol resulted in changes on: heart rate ($\Delta = 74.94\%$; $ES = 0.57$), systolic blood pressure ($\Delta = 20.67\%$; $ES = 0.27$), diastolic blood pressure ($\Delta = 6.91\%$; $ES = 0.15$) and rate pressure product ($\Delta = 111.78\%$; ES = 0.48). The 15/65% protocol resulted in alterations on: heart rate ($\Delta = 06.77\%$; $ES = 0.39$), systolic blood pressure ($\Delta = 16.85\%$; $ES = 0.35$), diastolic blood pressure ($\Delta = 3.38\%$; ES = 0.13) and rate pressure product ($\Delta = 96.41\%$; ES = 0.30). Increases in all variables pre to post resistance exercise were observed for all protocols ($p < 0.05$). When comparing the three different protocols, it was found that the heart rate ($p < 0.001$), systolic blood pressure ($p < 0.034$) and rate pressure product ($p < 0.001$), were more elevated in the 4/90% compared to the 15/65%.

Conclusion: The bench press exercise performed with low volume and high intensity promotes a more pronounced cardiovascular response compared to the same exercise performed with high volume and low intensity.

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\section*{La respuesta cardiovascular al entrenamiento de fuerza se ve más afectada por la intensidad que por el volumen en sujetos sanos}

RESUMEN

Objetivo: Determinar y comparar las respuestas cardiovasculares para tres protocolos de ejercicios de fuerza con diferentes volúmenes e intensidades.

Método: Fueron evaluados 15 sujetos sanos, con experiencia en ejercicios de fuerza, que realizaron el ejercicio de press de banca con tres volúmenes e intensidades diferentes, con 48 horas de diferencia, siguiendo un diseño cruzado: a) cuatro repeticiones al 90% de una repetición máxima (4/90%), b) ocho

Palabras clave:
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Presión arterial

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Reposta cardiovascular ao treinamento de força é mais afetada pela intensidade do que pelo volume em indivíduos saudáveis

RESUMO

Objetivo: Determinar e comparar as respostas cardiovasculares a três protocolos de exercícios resistidos (ER) com diferentes volumes e intensidades.

Métodos: Foram avaliados 15 indivíduos saudáveis, experientes em ER, que realizaram o exercício de supino com três volumes e intensidades diferentes, separadas por 48 horas, seguindo um delineamento cruzado: a) quatro repetições a 90% de uma repetição máxima (4/90%), b) oito repetições a 80% de uma repetição máxima (8/80%) e c) 15 repetições a 65% de uma repetição máxima (15/65%). Imediatamente após cada protocolo foram realizadas medidas de frequência cardíaca, pressão arterial sistólica e diastólica, que foram utilizadas para calcular o duplo produto.

Resultados: O protocolo 4/90% apresentou alterações em: frequência cardíaca (Δ = 84.57%; p < 0.001), pressão arterial sistólica (Δ = 24.03%; p = 0.024), pressão arterial diastólica (Δ = 0.47%; p = 0.024) e duplo produto (Δ = 125.65%; p = 0.04). O protocolo 8/80% resultou alterações em: frequência cardíaca (Δ = 74.94%; p = 0.57), pressão arterial sistólica (Δ = 6.91%; p = 0.15) e duplo produto (Δ = 111.78%; p = 0.48). O protocolo 15/65% apresentou alterações em: frequência cardíaca (Δ = 66.77%; p = 0.38), pressão arterial sistólica (Δ = 16.85%; p = 0.35), pressão arterial diastólica (Δ = 3.38%; p = 0.13) e duplo produto (Δ = 64.1%; p = 0.36). Se observaram aumentos em todas as variáveis previamente ao pós-teste. Comparando os três protocolos, obtém-se que a frequência cardíaca (p < 0.001), a pressão arterial sistólica (p = 0.034) e o duplo produto (p < 0.001) foram mais elevados no 4/90% em comparação com 15/65%.

Conclusão: A realização do exercício de supino com baixo volume e alta intensidade promove uma resposta cardiovascular mais acentuada que sua realização com alto volume baixa intensidade.

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to safely prescribe RE. Although there is not a consensus in the literature as to which factor promotes greater cardiovascular stress (volume or intensity), we hypothesized that an upper limb exercise protocol prioritizing greater intensity would result in a larger cardiovascular overload than a protocol prioritizing volume.

Thus, this study aimed to determine and compare the cardiovascular responses to three RE protocols performed with different volumes and intensities.

**Methods**

Fifteen healthy and asymptomatic males with a minimum RE experience of one year were evaluated. Exclusion criteria were: a) musculoskeletal limitations that were contraindicated for exercise; b) PAR-Q positive; c) diagnosis of hypertension or other cardiovascular disease and d) use of drugs that could influence the cardiovascular responses at rest or exercise. All procedures were approved by the Ethics Committee on Human Research at Federal University of Viçosa (Ref. N° 072/2010).

The body weight and height were measure following international standards for anthropometric assessment.12

The One Maximal Repetition (1RM) test was performed on a bench press apparatus (FS3060 model, Righetto, Brazil). All subjects underwent three sessions of 1RM tests with intervals of 48–72 h between each session for the evaluation of muscle strength.

The 1RM test was preceded by a warm-up set (10–12 repetitions) with approximately 50% of the load to be used at the first attempt of the 1RM test. The testing started two minutes after the warm-up. Each subject started the 1RM trials with a weight they believed they could lift only once using maximum effort. Weight increments were then added until they reached the maximum load that could be lifted once. If the participant could not perform a single repetition, 2.4–2.5% were subtracted from the load employed in the test.8 The subjects rested for 3–5 min between the attempts. All subjects made a maximum of three attempts to determine the 1RM. The form and the technique used in the performance of each exercise was standardized and continuously monitored in an effort to ensure the quality of the data. In addition, the subjects performed the tests at the same time of the day and did not practice any physical exercise, external to the program, during the experimental period. To reduce possible errors in the 1RM measures, the strategies were adopted according Moreira et al.11

After determination of 1RM, load percentages were calculated. Protocol 1: four repetitions at 90% of 1RM (4/90%); Protocol 2: eight repetitions at 80% of 1RM (8/80%) and Protocol 3: 15 repetitions at 65% of 1RM (15/65%).

The procedure for evaluating cardiovascular responses consisted of performing a series of volume and intensity-dependent protocols, with a time of two seconds each for concentric and eccentric phases guided by a metronome. The three protocols were performed with 48-h interval between exercise sessions.

To avoid a treatment order effect interfering with the results, we used a balanced crossover design, based on Latin Squares, so that each group of five subjects, determined at random, performed a different sequence of protocols.8,9,11 Thus, a group of subjects performed the sequence: Protocol 1–Protocol 2–Protocol 3; another group performed the sequence 2–3–1; and another group used the sequence 3–1–2; so that all volunteers performed three exercise protocols, always observing the prescribed rest interval between test days.

Before the execution of the protocols, the subjects remained lying at rest for 10 min in a calm and quiet environment. The resting heart rate (HR) was measured as the average of the last two minutes using a heart rate monitor (Polar S610, Finland). SBP and DBP were measured at rest using an auscultatory indirect method with the aid of an aneroid sphygmomanometer (Premium Brand Model: Single, China) following the recommendations of the Brazilian Society of Cardiology.13 During exercise, HR was measured by registering the highest value presented at the end of the series and SBP and DBP were measured with the cuff being inflated during the last repetition and reading being performed within a maximum of 10 s after the last repetition.11,14

Data were stored and analyzed using Sigma Stat (Sigma State for Windows, version 2.03). Data normality was assessed by the Kolmogorov–Smirnov test. Two-way ANOVA were used to check for differences between pre and post exercise and between the three different protocols for all variables, with a significance level of p < 0.05. The effect size was calculated by Cohen’s f².

**Results**

The anthropometric characteristics of the participants and 1RM data are presented in Table 1.

When comparing the pre and post-exercise time points in the three exercises, significant differences for all variables were observed, except for DBP in 15/65%. Table 2 shows the comparison of HR, SBP, DBP and RPP before and after the performance of bench press exercise at three different volumes and intensities. Moreover, significantly differences were found between 4/90% and 15/65% for HR (p < 0.001), SBP (p = 0.034) and RPP (p < 0.001) measured immediately following the bench press exercise.

**Discussion**

Studies to date that have investigated the cardiovascular response to RE did so by altering only intensity, or volume, but not both, or by studying only one variable, e.g. blood pressure. This study represents one of the few studies than compare the cardiovascular stress caused by different volumes and intensities of RE. Our main results were: (i) the three protocols promoted significant increases in HR, SBP and DBP from rest to exercise; (ii) no alterations in DBP were found in any of the evaluated protocols from rest to exercise and (iii) the protocol that emphasized the intensity (4/90%) promoted greater increase in HR, SBP and DBP, than the protocol which emphasized the volume (15/65%).

HR, SBP, DBP and RPP all increased from resting conditions, similar to that observed in other studies.8,9,11,15 In 1985, the study conducted by MacDougall et al.9 suggested that compression of the vascular bed by the muscles involved in the effort would be one of the factors responsible for a hemodynamic increase. In this perspective, the magnitude and duration of the muscle compression may be different according to the exercise design (load, sets, repetitions and muscle mass). In addition, high-intensity resistance exercise can also reduce the supply of oxygen to active muscles causing accumulation of local metabolites, stimulation of chemoreceptors and increased HR and cardiac contractility. This is a possible explanation for our results. Further, this common finding of increased cardiovascular stress also can be explained by increased sympathetic and decreased parasympathetic modulation, due to the increased activation of both chemoreceptors and muscle and joint mechanoreceptors.16 This could occur probably by two mechanisms: 1) by sending impulses from the motor cortex to the cardiovascular control center 17 and 2) by the increase in peripheral vascular resistance caused by partial occlusion of blood flow.18

The only parameter that showed no change from rest to exercise was the DBP for the 15/65% protocol. This is similarly to another study6 that assessed cardiovascular responses to three types of execution of the bench press, reporting no significant differences in DBP between pre and post-exercise stages. Likewise, Brito et al.,
Thus, 3,10 129.65% 20.67% Furthermore, 20.67%

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Anthropometric and one Maximal Repetition data.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Average</td>
</tr>
<tr>
<td>Age (years)</td>
<td>21.60</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>80.93</td>
</tr>
<tr>
<td>Stature (cm)</td>
<td>179.87</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.97</td>
</tr>
<tr>
<td>IRM (kg)</td>
<td>103.20</td>
</tr>
</tbody>
</table>

IRM, one maximal repetition; BMI, body mass index; SD, standard deviation.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Comparison of Heart Rate, Systolic Blood Pressure and Rate Pressure Product responses before and immediately following bench press resistance exercise performed at three different volumes and intensities.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Pre exercise</td>
</tr>
<tr>
<td>4/90% (load: 92.88 ± 16.42 kg)</td>
<td></td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>66.93 ± 7.98</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>119.33 ± 5.94</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>78.67 ± 3.52</td>
</tr>
<tr>
<td>RPP (mmHg,bpm)</td>
<td>7974.67 ± 885.81</td>
</tr>
<tr>
<td>8/80% (load: 82.56 ± 16.40 kg)</td>
<td></td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>67.87 ± 8.15</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>119.33 ± 7.04</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>77.33 ± 4.58</td>
</tr>
<tr>
<td>RPP (mmHg,bpm)</td>
<td>8085.33 ± 929.98</td>
</tr>
<tr>
<td>15/65% (load: 67.08 ± 11.86 kg)</td>
<td></td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>66.73 ± 7.37</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>118.67 ± 5.16</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>78.67 ± 5.16</td>
</tr>
<tr>
<td>RPP (mmHg,bpm)</td>
<td>7914.67 ± 874.12</td>
</tr>
</tbody>
</table>

HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; RPP, rate pressure product.

1 p < 0.05 for comparison with the same variable between pre and post.
2 p < 0.05 for comparison with 15/65%.

who compared the blood pressure response after RE of different body segments in hypertensive patients, found no significant difference between DBP during exercise and the resting condition. Considering that DBP represents the lower pressure exerted on the walls of arteries during ventricular diastole when blood is reaching in ventricles cavities, it is possible to infer that, the protocols used were not able to induce changes in this variable. Further, the DBP varies little during moderate exercise when compared to other cardiovascular variables, such as SBP and HR, since the systemic pressure during cardiac diastole tends to remain similar to resting levels.

The analyzed cardiovascular variables showed greater response during the protocol of higher intensity and lower volume (4/90%) compared to the protocol of lower intensity and higher volume (15/65%). Thus, we can infer that during dynamic RE, intensity has more pronounced effects on cardiovascular stress than the volume of exercise. Furthermore, there appears to be a dose-response effect in the relationship between exercise intensity and cardiovascular response, that is, a higher intensity will promote a greater cardiovascular response. It is therefore important to note that when prescribing RE for individuals for whom the elevation of cardiovascular load implies risk to the individual’s health, it is advisable to opt for lower training intensities, since these produce smaller increases in cardiovascular response. Thus, our findings add novel information to the body of scientific literature that clarifies the cardiovascular response to RE. This will allow a safer prescription of RE, particularly for individuals with cardiovascular disease.

A possible mechanism that explains this sharp increase in HR, SBP and RPP as a function of exercise intensity may be related to increased sympathetic nerve activity, which is triggered by the activation of the central nervous command and the muscle chemoreceptors that are activated by metabolites produced during muscle contraction involving some occlusive component. The metabolites are accumulated due to the mechanical obstruction of blood flow. Likely due to increased sympathetic activity, we observed an increase in HR and SBP. Furthermore, the production of metabolites in muscle causes local vasodilation in the active muscles, generating a reduction in peripheral vascular resistance. Thus, during the dynamic RE there is an increase in SBP and reduction or maintenance in DBP, a fact that was also observed in this study.

Additionally, Brito et al. reported that the execution of RE with large muscle groups with intensities greater than 70% of 1RM must be monitored because they can trigger pressure peaks, particularly in individuals with cardiovascular risk factors. This abrupt cardiac stress stems from the increased muscle mass recruited during exercise, leading to increased blood flow and the resultant higher end-diastolic volume, increased cardiac output and subsequent increase in blood pressure. The results of this study indicate that it would be better for individuals beginning RE, especially for those who should avoid high cardiovascular stress, to perform RE with lower intensity and higher volume because this exercise protocol caused gradual and less pronounced increases in HR, SBP and RPP.

The present study has potential limitations with regard to the number of repetitions and total exercise volume performed at each different load (4/90%; 8/80%; 15/65%). If multiple sets were performed, rather than the single set used in the current study, there could be a greater increase in cardiovascular stress due to the summation effect of the sets on cardiovascular response. Another limiting factor is the composition of the sample, as individuals in the present study were young and healthy, and therefore extrapolation of the results to individuals with disease is limited.

In conclusion, the present data indicate that HR, SBP and RPP increased significantly from rest to exercise in nearly all forms of RE, and that this increase is more pronounced in high-intensity exercise with low volume than during low- or moderate-intensity exercise despite the higher total exercise volume performed.

Furthermore, a possible practical application of the results of this study is the decision-making by professionals working with RE prescription, particularly, when these professionals are prescribing RE for individuals in at-risk groups, such as patients with hyper-tension and heart disease, in whom the acute pressure response to these exercises serves as a trigger for cardiovascular events. Accordingly, it is recommended to opt for RE protocols that favor moderate or low intensity and high or medium volume due to the less pronounced effect of increased cardiovascular stress.

Ethical disclosures

Protection of human and animal subjects. The authors declare that were followed all ethical procedures for experiments with humans in this investigation.

Confidentiality of data. The authors declare that no patient data appears in this article.

Right to privacy and informed consent. The authors declare that no patient data appears in this article.

Conflicts of interest

The authors have no conflicts of interest to declare.

References


