Effect of Resistance Training on Blood Pressure and Autonomic Responses in Treated Hypertensives

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1Biomedical Engineering Program, COPPE, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil; 2School of Physical Therapy, Federal University of Juiz de Fora, Juiz de Fora, Brazil; 3University Hospital Pedro Ernesto, University of the State of Rio de Janeiro, Rio de Janeiro, Brazil; and 4School of Physical Education and Sports, Federal University of Juiz de Fora, Juiz de Fora, Brazil

ABSTRACT

Trevizani, GA, Seixas, MB, Benchimol-Barbosa, PR, Vianna, JM, da Silva, LP, and Nadal, J. Effect of resistance training on blood pressure and autonomic responses in treated hypertensives. J Strength Cond Res 32(5): 1462–1470, 2018—This study evaluated the effect of resistance training (RT) on heart rate variability (HRV) and on blood pressure (BP) responses to acute and short-term exposure in treated hypertensive (HT) subjects. Twenty-one men participated in the study, 8 HT under drug treatment regimen and achieving adequate BP control before inclusion and 13 normotensive (NT). The RT protocol consisted of 12 sessions with eight exercises (leg extension, leg press, leg curl, bench press, seated row, triceps push-down, seated calf flexion, and seated arm curl) performed for two sets of 15–20 repetitions with 50% of one repetition maximum with 2-minute rest intervals in between sets, 3 × 1/week. Heartbeat measurements were taken before and after RT, and BP was measured at the beginning and at the end of each session after 10-minute rest. The repeated measures analysis of variance (effect: group vs. training) evaluated BP and HRV responses. Effect size (ES) calculation measured the magnitude of the RT effect on these variables. There was a statistically significant reduction in postexercise systolic BP in both groups (p = 0.040), without significant change in resting BP along RT (p = 0.159). Regarding HRV, it was observed a reduced sympathetic-vagal balance (training interaction vs. group: p = 0.058, ES = −0.83) in HT subjects. Resistance training promotes a significant acute reduction of BP in the HT and NT groups and provides a slight benefit of cardiac autonomic balance in the HT.

KEY WORDS hypertension, heart rate variability, resistance exercise

INTRODUCTION

Aterial hypertension (HTN) is a highly prevalent chronic medical condition, characterized by high and sustained levels of blood pressure (BP) (24). Its progression can cause structural and functional changes in target organs and in the metabolic system, leading to clinical complications and increased risk of cardiovascular morbidity and mortality (2).

Cardiac autonomic dysfunction, evidenced by an increase in cardiac sympathetic activity, reduction in vagal modulation, or both, is one of the main pathophysiological mechanisms for the development, establishment, and progression of HTN (18). Studies have shown that hypertensive (HT) subjects presented an impairment in cardiac autonomic modulation, indicated by reduced heart rate variability (HRV) (32,34). This reduction is related to a higher risk of morbidity and mortality as well as worse prognosis and general health condition, being a functional marker to cardiac autonomic health (40).

One of the main nonpharmacological strategies for prevention, control, and treatment of HTN and its future complications is physical exercise (4,16). A single bout of aerobic exercise is able to promote sustained reduction of BP after its ending and leads to an acute effect of exercise, known as postexercise hypotension (PEH) (14). Furthermore, there is a consensus in the literature that regular physical aerobic exercise reduces pressure levels chronically (1) and improves cardiac autonomic modulation (5) in HT subjects.

However, resistance training (RT) is recommended for the senescent population and with cardiovascular risk factors as an additional strategy to aerobic training given their peripheral effects such as mass gain and muscle strength and endurance (10). However, it has not been established in
the literature whether RT is able to act beneficially on the cardiovascular system providing autonomic and hemodynamic adaptations in subjects with cardiovascular risk factors. Similarly, it is also unknown whether cardiovascular responses to resistance training program differ between treated HT and normotensive (NT) subjects.

Therefore, the aim of this study was to test the hypothesis that RT will result in BP response to acute exposure and in HRV and BP responses to short-term exposure in treated HT subjects, and these responses will be different from those presented by NT subjects.

**METHODS**

**Experimental Approach to the Problem**

To examine the hypothesis of the present investigation, all volunteers recruited to the research underwent the experimental protocol described below to evaluate the behavior of dependent variables, HRV measurements, and BP, regarding the independent variables, time (before and after RT) and group (treated HT and NT).

The muscular strength and endurance were analyzed to confirm the expected improvement in muscle performance from the RT protocol proposed.

**Subjects**

Twenty-one men took part in the study, and they were divided into two experimental groups: hypertensive group (HT), composed of 8 subjects with a medical diagnosis of HTN and adequate BP control, under anti-HT drug therapy (treatment period = 10.1 ± 6.5 years; Table 1), and normotensive group (NT), composed of 13 healthy subjects (Table 2). All volunteers were recruited considering the following inclusion criteria: male, aged 50 years or older, who have not been smoking for at least 1 year. To eliminate the effects of previous physical exercise, only subjects who have not practiced physical exercise for less than or equal to one session a week for a minimum of six months

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**Table 1. Antihypertensive drugs.**

<table>
<thead>
<tr>
<th>Pharmacological class</th>
<th>No. of volunteers</th>
<th>Percentage (%)</th>
</tr>
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<tbody>
<tr>
<td>Without medication</td>
<td>1</td>
<td>12.5</td>
</tr>
<tr>
<td>On medication</td>
<td>7</td>
<td>87.5</td>
</tr>
<tr>
<td>Monotherapy</td>
<td>4</td>
<td>50.0</td>
</tr>
<tr>
<td>Diuretic</td>
<td>1</td>
<td>12.5</td>
</tr>
<tr>
<td>Calcium channel blockers</td>
<td>1</td>
<td>12.5</td>
</tr>
<tr>
<td>Angiotensin receptor antagonists</td>
<td>2</td>
<td>25.0</td>
</tr>
<tr>
<td>Combination of therapies</td>
<td>3</td>
<td>37.5</td>
</tr>
<tr>
<td>Angiotensin receptor antagonists and diuretic</td>
<td>1</td>
<td>12.5</td>
</tr>
<tr>
<td>Angiotensin receptor antagonist and calcium channel blocker</td>
<td>1</td>
<td>12.5</td>
</tr>
<tr>
<td>Angiotensin receptor antagonist, calcium channel blocker, and diuretic</td>
<td>1</td>
<td>12.5</td>
</tr>
</tbody>
</table>

**Table 2. Sample characterization.**

<table>
<thead>
<tr>
<th>Demographic variable</th>
<th>HT (n = 8)</th>
<th>NT (n = 13)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>59.0 ± 7.6</td>
<td>57.1 ± 6.0</td>
<td>0.53</td>
</tr>
<tr>
<td>Anthropometric variables</td>
<td></td>
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</tr>
<tr>
<td>Body mass (kg)</td>
<td>86.2 ± 16.0</td>
<td>78.4 ± 13.2</td>
<td>0.24</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.7 ± 0.1</td>
<td>1.7 ± 0.1</td>
<td>0.65</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.8 ± 4.0</td>
<td>25.8 ± 4.1</td>
<td>0.12</td>
</tr>
<tr>
<td>Hemodynamic variables (mm Hg)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SBP</td>
<td>133.4 ± 7.0</td>
<td>127.0 ± 8.0</td>
<td>0.09</td>
</tr>
<tr>
<td>DBP</td>
<td>85.9 ± 7.6</td>
<td>82.1 ± 5.7</td>
<td>0.23</td>
</tr>
<tr>
<td>MAP</td>
<td>101.7 ± 6.7</td>
<td>92.8 ± 17.3</td>
<td>0.02</td>
</tr>
</tbody>
</table>

*HT = hypertensive group; NT = normotensive group; n = sample size; BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure; MAP = mean arterial pressure.
**Variables described as mean ± SD.
†Statistical difference related to HT (p ≤ 0.05).
were included in the study. The research excluded volunteers with a history of cardiovascular, metabolic, liver or thyroid diseases, or central nervous system degenerative disorders, as well as osteoarticular diseases that would limit the execution of a resistance training program. Volunteers who had a history of or presented arrhythmias during electrocardiographic monitoring at rest were also excluded. No subject in the HT group had been using beta-blocker medication for at least four weeks before the enrollment and during the study protocol.

The study was approved by the Ethics Committee of the Federal University of Juiz de Fora (approval number 65/2011), and each subject subsequently signed an informed consent document before participation.

**Procedures**

**Initial Evaluation.** All volunteers underwent clinical assessment, consisting of (a) medical history; (b) physical examination and BP measurement; (c) anthropometric measurements, including height, and body mass, calculation of body mass index (BMI = weight body [kg]/height [m^2]), waist-hip ratio, and body fat percentage, with appropriately calibrated devices; and (d) 12-lead standard resting electrocardiography (Funbec, Brazil). Measurements of systolic (SBP) and diastolic blood pressure (DBP) were taken by cardiography (Funbec, Brazil). Measurements of systolic (SBP) and diastolic blood pressure (DBP) were taken by auscultation held in a single measurement after 10 and 20 minutes of rest in supine position—the mean value of these measurements was considered to characterize the sample.

The mean arterial pressure (MAP) was calculated through equation 1:

\[
\text{MAP} = \frac{2 \times \text{DBP} + \text{SBP}}{3}
\]

**Measurement and Processing of Heart Rate for Heart Rate Variability Analysis.** All volunteers had their beat-to-beat heart rate recorded before and after the resistance training program so as to evaluate cardiac autonomic modulation through HRV analysis. To conduct the experiment, the volunteers were previously instructed to refrain from taking caffeinated and alcoholic beverages for 24 hours before the assessment and to have a good night’s sleep.

Heartbeats were collected using an RS800CX heart rate monitor (Polar, Kempele, Finland), according to the instructions of the manufacturer, in an appropriate acclimatized and quiet environment, always during the morning. After a 10-minute rest in supine position, heartbeats were recorded during 10 minutes in spontaneous respiration.

The specific values of the intervals between each heartbeat RR intervals (RRI) were collected and transmitted to a computer using Polar Precision Performance software (Polar) through an infrared interface from the same manufacturer. In this application, the initial 5 minutes of RRI signals were selected, and this time series was later transferred to Kubios HRV Analysis software, version 2.0 (36). In this application, the

<table>
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<th>Table 3. Assessment of muscular strength and endurance.*†</th>
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<tr>
<td><strong>Equipment</strong></td>
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<tr>
<td><strong>Muscular strength (kg)</strong></td>
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<tr>
<td>Leg extension</td>
</tr>
<tr>
<td>Bench press</td>
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<tr>
<td>Leg press</td>
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<tr>
<td>Seated row</td>
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<tr>
<td>Leg curl</td>
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<tr>
<td>Triceps push-down</td>
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<tr>
<td>Seated calf flexion</td>
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<tr>
<td>Seated arm curl</td>
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<tr>
<td><strong>Muscular endurance (no. of repetitions)</strong></td>
</tr>
<tr>
<td>Leg extension</td>
</tr>
<tr>
<td>Bench press</td>
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<tr>
<td>Leg press</td>
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<td>Seated row</td>
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<tr>
<td>Leg curl</td>
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<td>Triceps push-down</td>
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<tr>
<td>Seated calf flexion</td>
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<td>Seated arm curl</td>
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</table>

*HT = hypertensive group; NT = normotensive group; RT = resistance training; ES = effect size.
†Variables described as mean ± SD.
‡Statistical difference related to before RT in the same group (p < 0.05).
correction of artifacts and premature beats was conducted using the average level filter procedure to obtain the time series of sinus RR intervals normal to normal intervals (NNI).

The mean duration of NNI (MNN) was calculated as well as the following HRV indices in the time domain: SD of NNI (SDNN) and root mean square of the difference between successive NNI (RMSSD). The SDNN index reflects the participation of all the rhythmic components responsible for variability, being related to the contributions from both branches of the autonomic nervous system, whereas the RMSSD index reflects the contributions of variations at high frequencies (HF), which are related to the vagal activity (38).

The HRV indices were also calculated in the frequency domain by estimating the power spectral density (PSD) function using the Fast Fourier Transform (17). Therefore, it was performed the removal of the trend component of the time series of NNI using the a priori smoothing method (37), and the interpolation using the cubic spline sampled at a 4-Hz frequency. From the PSD, the following HRV indices were calculated: power of the spectral bands of low frequencies (LF; 0.04–0.15 Hz) in absolute units (ms²) that represent a set of sympathetic and vagal influences on the sinus node (SN) and in normalized units (nu) that represent predominantly the sympathetic action on the SN (38); power of the spectral bands of HF (0.15–0.4 Hz) in absolute (ms²) and normalized (nu) units that represent the vagal activity on the SN (38); and LF/HF ratio, whose value can be interpreted as an indicator of sympathetic-vagal balance (38).

Familiarization and Assessment of Muscular Strength and Endurance. The volunteers had three sessions to familiarize themselves with the environment where they underwent the RT, as well as with the weight-training equipment and the proper techniques for each exercise.

Two sessions were made on nonconsecutive days to evaluate muscular strength. One maximum repetition (1RM), which is defined as the maximal weight that can be lifted at once with correct lifting technique (8), was tested and retested for each exercise. The test was performed with increasing loads up to five repetitions for each exercise, with rest intervals of 3–5 minutes. Retesting was done at the next session, based on the maximal load obtained from the test. Differences up to 5% were considered acceptable, and the highest load reached was used for the training prescription. In the next session, the repetition weight test was used, which consists of the maximum number of complete repetitions with a load equal to 50% of the value of one repetition maximum (1RM) obtained in the test and retesting sessions to assess muscular endurance (8).

At the end of the training program, muscular strength and muscular endurance were reevaluated.

Resistance Training Program. The volunteers underwent 12 sessions of supervised resistance exercise using weight-training equipment (Righetto, Pro R line, Brazil) three times a week on nonconsecutive days. Each session consisted sequentially of two sets of 20 repetitions for the following exercises: leg extension, leg press, leg curl, bench press, and seated row; and 15 repetitions for the following exercises:

![Figure 1](https://example.com/fig1.png)

**Figure 1.** Indices of heart rate variability in time (panel A) and frequency domains (panel B), before and after resistance training (RT). HT = hypertensive group; NT = normotensive group. HF = high frequency; LF = low frequency.
triceps push-down, seated calf flexion, and seated arm curl. The order of execution of exercises was alternated between the upper and lower limbs. The adopted training load was 50% of 1RM, and the rest interval between sets and exercises was of 2 minutes. On the sixth training session, the training load intensity was increased approximately by 5% and maintained until the end of the program.

At the beginning and end of each resistance exercise session, BP was measured using the oscillometric method with an automatic digital machine MAM PC model (Micro-life, Brazil, Reference: MIB-P3AC1-1 PC), validated according to the criteria of the British Society of Cardiology (6). The measurements were taken after a 10-minute rest period in sitting position. The cuff was placed on the right arm and the general procedure followed the recommendations of the 7th Brazilian Guideline of Arterial Hypertension (16).

Statistical Analyses
For all statistical tests, a probability level of $p \leq 0.05$ denoted statistical significance. The Shapiro-Wilk normality test was used to verify evidence of normal data distribution, and from the results, the appropriate tests were selected.

Parametric Student’s $t$-test for independent samples and nonparametric Wilcoxon test were used to compare the demographic, anthropometric, and hemodynamic variables between groups.

The two-factor analysis of variance with repeated measures (ANOVA) was used to analyze the behavior of SBP and DBP: (a) in each workout session (pre-exercise vs. post-exercise—acute response), (b) during the training program (pre-exercise along the training—response to short-term exposure), and (c) between the groups (HT vs. NT); to compare the values of the difference between pre-exercise and postexercise SBP and DBP (a) during the training program (response to short-term exposure) and (b) between the groups (HT vs. NT); to compare the variables muscular strength, muscular endurance, and HRV indices, evaluated before and after the RT (time effect) and between the experimental groups (group effect). Subsequent Tukey’s post hoc tests were used to determine differences when significant main effects were obtained. In order for this analysis to be applied to HRV indices that showed no evidence of normal distribution, its transformation in natural logarithm (ln) was made.

Complementing the statistical tests described above, effect size (ES) was calculated, given by the difference between the average of pretraining and posttraining values divided by the $SD$ of the pretraining values (28). To calculate the ES of acute SBP and DBP responses, it was considered the average of the 12 measurements taken in the RT sessions for pre-exercise and postexercise; and for the response to short-term exposure, it was used the average of the pre-exercise

![Figure 2. Behavior of systolic blood pressure (SBP) (panel A) and diastolic blood pressure (DBP) (panel B) at the beginning (pre) and end (post) of each session of resistance training for hypertensive (HT) and normotensive (NT) groups. The markers represent the mean values and the vertical bars the SE.](image)
measured values (rest) in the first and last sessions of the training protocol. Effect size was used to determine the magnitude of the effect of the RT on each of HRV indices, on BP responses to acute and short-term exposure, and on muscular strength and muscular endurance variables in each exercise performed. All ES calculations were performed individually in the HT and NT groups. The scale proposed by Rhea (28) was used to determine the magnitude of ES in subjects untrained as follows: trivial <0.5; small 0.5–1.25; moderate 1.25–1.9, and larger >2.0.

Statistical analyses were performed using GraphPad Prism version 5.0 (GraphPad Software) and Statistica version 8.0 (Statsoft) software.

RESULTS

The two studied groups were matched in terms of demographic and anthropometric characteristics (Table 2). Although MAP was slightly higher in HT, both SBP and DBP showed no significant differences between groups.

The RT caused a significant increase in muscular strength in all muscle groups trained in both experimental groups, except for the knee flexors in both groups (Table 3), with no differences between them. Muscular endurance showed similar results to the maximum one, but without significant increase to the knee flexors in the NT group (Table 3). The magnitude of ES showed that the increase of muscular endurance was greater than muscular strength (Table 3).

Regarding cardiac autonomic modulation, there were no significant differences in the MNN and HRV indices in the time domain between the evaluations conducted before and after RT (Figure 1A). As to the contents of HRV in the frequency domain, although there was no statistically significant difference, it was possible to identify increase in the HF index in normalized units (training × group interaction: \( \rho = 0.085 \) and ES = 0.80) and of decrease not only in the LF index in normalized units (training × group interaction: \( \rho = 0.085 \) and ES = −0.80) but also in ln LF/HF (training × group interaction: \( \rho = 0.058 \) and ES = −0.83) in the HT group (Figure 1B).

The results of the analysis of variance for the SBP data revealed the existence of statistically significant difference between groups (\( \rho = 0.047 \)), with higher pressure values for the HT group and evidence of significant reduction in post-exercise SBP compared with the pre-exercise values (acute effect) in both experimental groups (\( \rho = 0.04 \), HT: ES = −0.75; NT: ES = −0.59), without significant modifications of the pre-exercise or rest values along the training (short-term exposure) for both groups (\( \rho = 0.159 \), HT: ES = −0.50; NT: ES = −0.23). Responses to acute and short-term exposure to the studied RT were not evidenced in relation to DBP values, and there was no difference between the groups for this variable. The behavior of SBP and DBP in both experimental groups is shown in Figures 2A, B, respectively.

DISCUSSION

This study investigated the effect of a resistance training program of low intensity and short duration on BP responses to acute and short-term exposure and on cardiac autonomic modulation in treated HT and NT subjects. The results showed that the resistance training program: (a) was effective for muscular endurance and strength gain; (b) promoted acute BP response, with evident reduction of SBP after the resistance exercise sessions compared with rest (PEH); (c) showed a slight improvement in cardiac autonomic balance, suggested from the increase of the HF index (nu) (42.24%), and of reduction of both LF (nu) (22.89%) and of ln LF/HF (101.38%) indices, which were of low magnitude and evident only in the HT-treated group.

Hypertension is one of the major cardiovascular risk factors, accounting for 40% of deaths from cerebrovascular accident and 25% from coronary artery disease (2), whose prevalence in the Brazilian population ranges from 23.3 to 43.9% (16), and it is directly related to age (24). Cardiac autonomic dysfunction is an important pathophysiological mechanism for the development of HTN and its clinical complications (18). Hence, the development of research with interventions that give rise to benefits for cardiovascular health is relevant and imminent, and are able not only to reduce BP levels but also to improve cardiac autonomic modulation and, consequently, minimize the risk of fatal cardiovascular events and functional losses.

Although this study has not shown basal differences of cardiac autonomic modulation, evaluated by HRV between HT and NT, the results indicate that RT promoted slight improvement in cardiac autonomic balance only in the HT group. These findings suggest that HT subjects under these conditions may be more sensitive to the effect of RT.

In fact, although it has been poorly described in the scientific literature, the effect of RT on HRV in healthy young (11), middle-aged (15), or elderly individuals (12) has not been significant. Melo et al. (20) reported impairment in cardiac autonomic balance, which was revealed by an increase in LF (nu) and LF/HF indices and a decrease in the HF (nu) index, after submitting healthy elderly individuals to 12 weeks of moderate intensity RT. However, the beneficial effects of RT on HRV seem to be more evident in individuals with diseases concurrent to cardiac autonomic dysfunction, such as fibromyalgia (9) and heart failure (31).

In subjects with HTN, the results of studies on RT are still scarce and contradictory. Most of these studies have evaluated the effect of manual grasping isometric RT and found an increase in the HF index (39), improvement only on the complexity of heart rate evaluated by nonlinear analysis of HRV, without modifications in the indices in the time and frequency domains (21), and absence of changes in HRV in HT individuals (35). Evaluating the effect of the interaction between the training (dynamic resistance vs. aerobic) and the time (before vs. after RT) modes in nonmedicated
pre-HT individuals, Collier et al. (3) showed improvement in HRV in response to aerobic training and absence of changes with RT. These results suggest that, in this study, the association between RT and drug treatment of HTN has optimized the effect of RT on HRV.

Pressure response to RT has been increasingly described in the scientific literature. Postexercise hypotension has clinical importance in the control of BP in HT individuals (26), once the combination of the magnitude and duration of this acute response enables physical exercise to be recommended by health institutions as an important nonpharmacological intervention strategy for prevention, control, and treatment of this clinical condition (10). However, studies that have assessed this phenomenon because of resistance exercise are still scarce, especially considering multiple sessions, as was the case in the present investigation, and comparing HT and NT subjects.

Only two studies have investigated acute and chronic BP responses to RT, but none of them have evaluated the behavior of this response over all the sessions of the training program. Moraes et al. (22) submitted 15 middle-aged, HT, and sedentary men to a resistance training program which lasted 12 weeks during which anti-HT drugs in use were suspended. In this study, BP measurements were taken only in the first and last sessions of exercises of the analyzed resistance training program. The main findings were significant reduction in postexercise SBP in the first session and the absence of this response in the last session, indicating that PEH was suppressed by the chronic effect of training (pretraining SBP = 150 ± 13 mm Hg vs. postraining SBP = 134 ± 12 mm Hg). Mota et al. (23) evaluated HT elderly women under different anti-HT medication; during participation in a resistance training program with increasing intensity and lasting four months (first month: adaptation; second to fourth month: 60–80% of IRM), with BP measurements being performed at the end of each month of RT. Such measurements showed PEH for SBP in the second and third months of RT and that this acute response has not been verified in the last month of training, probably because of significant reduction of BP at rest from the second month of RT. Thus, PEH seems to be influenced by basal pressure values.

The nonuniform sampling information—regarding age, sex, physical activity practice, and usual medication—among the studies that have investigated the effects of RT on BP response can interfere in the investigated variables. In addition, these studies differ widely in relation to exercise prescription variables and RT such as intensity, volume, interval period between sets and exercises, muscle groups involved, among others.

There is no consensus in the literature about the ideal prescription of resistance exercise sessions to promote PEH. Few studies have assessed the influence of the intensity of the resistance physical exercise on PEH, and the findings show that the ones with greater intensity cause significant increase in PEH duration without interfering in the magnitude of this response (33), whereas those of lesser intensity provide a greater magnitude of PEH in relation to more intense ones (25) and that both intensities cause systolic PEH (27).

The studies that have evaluated the effect of different amounts of training on acute BP response (indicating volume as the number of sets performed in the resistance exercise sessions as the representative parameter of the amount of work done) found a greater magnitude and duration of PEH in greater volume sessions, regardless of the format of the session being conventional or in a circuit (19,30). However, the duration of the recovery interval between sets and exercises in one session of RT does not seem to influence PEH (7). Hence, the RT protocol that was investigated in this study seems to meet the main parameters of appropriate prescription for PEH and, at the same time, complies with the recommendations to this population (1,16), allowing a safe prescription and a better adherence to the training program, because of its low intensity.

Some review and meta-analysis studies have been developed in recent years to assess the effects of resistance training programs on chronic BP responses (13,29). Cornelissen et al. (4) evaluated 29 controlled and randomized trials on the effect of dynamic RT on this response, showing as an overall result a significant reduction of SBP and DBP levels. However, Rossi et al. (29), in a meta-analysis study that excluded the ones in which pressure response was not the primary effect of the intervention to be evaluated, have showed that RT is able to significantly reduce DBP but not SBP. From the above studies, it is understood that there is not a consensus that RT promotes chronic reduction in BP, considering that they have included samples with different ages, basal BP, and sex.

However, some longitudinal studies with training protocols similar to the ones in this study have showed chronic reduction of BP in middle-aged and elderly HT individuals after 12 (22) and 16 weeks of RT (23). This study showed no changes in basal BP along RT, possibly because of its short duration in relation to the aforementioned ones.

Possible limitations of this study include the nonstandardization of anti-HT drugs in the HT group, evaluation of pressure response during the training performed exclusively by tension values immediately before the resistance exercise session, small size of the sample, and the short duration of the total time of the resistance training program. The use of ES calculation to assess clinical relevance and not just statistical tests contributed to a better understanding of the effect of RT on autonomic and hemodynamic responses in the investigated population. However, the classification of the magnitude of the ES that we adopted in this study, proposed by Rhea (28), considers specifically the variables of muscle strength and endurance. Because of distinct statistical characteristics between these variables and those of HRV or BP, such as magnitude of average and SD, further
investigations and adjustments may be necessary to ensure that the sizes of the identified effects have not been underestimated.

Future studies should investigate the magnitude and duration of PEH using the ambulatory monitoring of BP, other RT methodologies with longer protocols to ratify the clinical importance of PEH, and improvement in cardiac autonomic balance as a response to RT in a population with similar characteristics to this study.

**Practical Applications**

The investigated RT program took in mind the subject adhesion, comprehending low intensity and short duration. Despite these characteristics, it was able to promote beneficial acute BP responses, without evidence of response to short-term exposure. It also tends to improve the cardiac autonomic balance in the treated HT volunteers. In addition, the applied RT protocol shows to be safe because none of the evaluated volunteers had muscle injuries or negative cardiovascular effects during its execution. This study reinforces the importance of RT as a promising intervention for HT patients, not only by promoting an increase in strength and muscle resistance and by aiding in BP control but also by improving cardiac autonomic modulation, thus contributing to prevent the development and progression of cardiovascular diseases.

**References**


