Cardiovascular Adaptations to Resistance Training in Elderly Postmenopausal Women

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Key words
- muscular strength
- blood pressure
- heart rate variability
- aging

Abstract

The purpose of this study was to investigate the effect of resistance training on resting blood pressure and heart rate variability in elderly postmenopausal women. 29 untrained, non-hypertensive elderly women were randomly assigned to 2 groups: an intervention group (n = 15, 65.5 ± 5.0 years, 57.3 ± 6.5 kg, 156.7 ± 5.1 cm) that underwent a supervised resistance training program (8 exercises, 2 sets, 10–15 repetitions, 3 times/week) or a control group (n = 14, 66.2 ± 4.1 years, 61.1 ± 11.7 kg, 157.5 ± 7.1 cm) that participated in a supervised stretching program (25–30 min/session, 2 times/week). Resting auscultatory blood pressure, heart rate variability, evaluated from short recordings in a seated position, and maximal dynamic strength (1-RM test) were measured at baseline and after 12 weeks. A group x time ANOVA revealed that muscular strength increased significantly in the resistance training group (+10.2% for bench press and +12.7% for leg extension, $P<0.05$). Systolic blood pressure was reduced significantly in the resistance training group from pre- to post-intervention period (−5 mmHg; $P<0.05$), while no significant effect was noted for diastolic blood pressure and heart rate variability indexes ($P>0.05$). None of these variables changed in the control group throughout the study. In conclusion, a supervised resistance training program improved muscular strength and reduced systolic blood pressure without affecting diastolic blood pressure and heart rate variability in elderly postmenopausal women.

Introduction

Hypertension is considered a major risk factor for the development of cardiovascular diseases [11], which are among the leading causes of morbidity and mortality worldwide [1]. In addition, a considerable increase in the prevalence of hypertension in many countries has been observed in recent years, affecting individuals of both sexes at different ages [16], but appearing more frequently in the elderly [4]. The decrease in estrogen production in women, especially after menopause, may lead to an increase in sympathetic activity and a decrease in endothelial function, which may increase blood pressure (BP) [25], enhancing the chances for developing hypertension [25]. This could explain the lower hypertension prevalence in middle-aged women than in men, and the greater potential for increases in BP in elderly women than men [25]. Thus, it is important to develop strategies that decrease blood pressure in elderly women to prevent hypertension.

The regular practice of physical exercise has been shown to produce a substantial decrease in BP [1, 36]. Thus, public health organizations have included aerobic training in their recommendations for hypertension prevention and treatment [1, 11, 47]. More recently, resistance training (RT) has also become part of these recommendations [1, 47], particularly due to its beneficial effects on muscle mass, power, and strength [6, 24]. However, the effects of RT on resting BP are not completely understood. Some studies have shown significant decreases in this variable [10, 34, 38, 40, 41, 46], while others reported no changes [14, 18, 43, 44]. Moreover, the literature on this topic is still scarce compared with studies involving predominantly aerobic exercises.

Additionally, autonomic nervous system may play a role in BP regulation and also in the pathogenesis of hypertension and many other cardiovascular diseases [39]. Heart rate (HR) variability (HRV) analysis is a non-invasive tool to evaluate the autonomic modulation to the heart [39]. It

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analyzes the variation of RR intervals during a period of time, therefore allowing the estimation of the sympathetic and parasympathetic modulations to the heart [39]. In the elderly, a significant reduction in HRV has been observed [26], and this adaptation has been associated with an increased risk of mortality [42]. Furthermore, reduced HRV has also been related to a number of pathological conditions, including hypertension [45]. Regular physical exercise has been reported to increase HRV, mainly in studies using aerobic training [17]. In regard to the impact of RT on HRV, the information is inconsistent, with preliminary reports showing a reduction in HRV in older men, particularly with eccentric RT performed with isokinetic equipment [27]. However, no change was noted in HRV in elderly women exercising with dynamic RT equipment [19]. Thus, more studies are needed to clarify this issue.

Given that RT is as an effective strategy for improving muscular strength and power in elderly women [6,24] and knowing that previous studies about the cardiovascular effects of RT have some important methodological limitations (i.e., lack of dietary intake control [10,14,18,38,43,44], lack of control group [14,38], or not individualized training [41]), the purpose of this investigation was to analyze the effect of 12 weeks of RT on BP and HRV in elderly women, controlling these limitations. We hypothesize that RT decreases BP, without changing the HRV. This hypothesis was based on previous studies that observed BP fall and attributed it to peripheral vascular adaptations [44,46], and other studies that did not report autonomic changes after RT [10,19].

Methods

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Subjects

31 untrained but otherwise healthy older women were recruited from the metropolitan area of Londrina, Paraná, Brazil, to participate in this research. 29 participants (65.9 ± 4.6 years, 60.4 ± 9.3 kg, 157.1 ± 6.0 cm, 24.5 ± 3.2 kg/m^2) finished the study and, therefore, were included in the analysis. The reasons for the 2 dropouts were insufficient attendance to the training sessions (< 85 % of the total sessions) by one subject and a car accident, by the other subject. All the participants completed health history and physical activity questionnaires. Subjects also underwent a diagnostic, graded exercise stress test with 12-lead ECG. Subjects were only included in the study if an evaluation by a cardiologist classified them as having no restriction for the participation in physical exercise. All subjects were free of any musculoskeletal or other disorders that might have affected their ability to complete RT and other tests. A written informed consent was obtained from each subject after a detailed description of all procedures was provided. This investigation, which is in accordance with the ethical standards of this journal [22], was approved by the local Research Ethics Committee.

As inclusion criteria, the elderly women were required to be apparently healthy, without hypertension (systolic blood pressure (SBP) < 140 mmHg and diastolic blood pressure (DBP) < 90 mmHg), diabetes, and cardiac or renal dysfunction. Additionally, the participants should not be taking drugs with inotropic or chronotropic actions, should be nonsmokers, non-users of hormonal replacement therapy, and should not have been involved in any regular practice of systematic physical activity for more than once a week over the 6 months preceding the beginning of the study.

Subjects were randomly assigned to a RT intervention group (TG) that underwent supervised RT sessions or a control group (CG) that participated in a supervised stretching program for 12 weeks. It is noteworthy that the participants from both groups received instructions not to perform any other type of systematic and regular physical activity during the entire period of the study.

Anthropometry

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Filizola, model ID 110, São Paulo, Brazil), with the subjects wearing light workout clothing and no shoes. Height was measured with a wooden stadiometer to the nearest 0.1 cm, while the subjects were standing without shoes. Body mass index (BMI) was calculated as body mass in kilograms divided by the square of height in meters. Anthropometric measurements were performed at baseline and after 12 weeks of intervention according to procedures described in the literature [21].

Body composition

Body composition measurements were carried out in the morning after an overnight fasting using a dual energy x-ray absorptiometry (DXA) scan (Lunar Prodigy, model NRL 41990, GE Lunar, Madison, WI). Before scanning participants were instructed to remove all objects containing metal. Scans were performed with the subjects lying in the supine position along the table's longitudinal centerline axis. Feet were secured together at the toes level in order to immobilize the legs while the hands were maintained in a prone position within the scanning region. The subjects remained motionless during the entire scanning procedure. Both calibration and analysis were carried out by a skilled laboratory technician. The calibration of the equipment followed the manufacturer's recommendations. The software generated standard lines that set apart the limbs from the trunk and head. These lines were adjusted by the same technician using specific anatomical points determined by the manufacturer. Analyses at baseline and after 12 weeks of intervention were performed by the same technician who was blinded to treatment intervention.

Muscular strength

Maximal dynamic strength was evaluated at baseline and after the intervention period using the 1-RM test in the bench press and leg extension exercises. The test for each exercise was preceded by a warm-up set (6–10 repetitions), with approximately 50 % of the estimated load used in the first attempt of the 1-RM test. This warm-up was also used to familiarize the subjects with the testing equipment and the lifting technique. The testing procedure was initiated 2 min after the warm-up. The subjects were instructed to try to complete 2 repetitions with the imposed load in 3 attempts in both exercises. The rest period was 3–5 min between each attempt. The 1-RM was recorded as the greatest resistance lifted with which the subject was able to complete only one single maximal execution [33]. Execution technique for each exercise was standardized and continuously monitored to guarantee the reliability of the maximum strength. All the sessions were supervised by 2 experienced researchers to ensure greater safety of the subjects during the tests [33]. Verbal encouragement was given throughout each test. 5 min after the end of the 1-RM bench press test, the subjects started the 1-RM leg extension test. 4 familiarization sessions were performed at baseline separated by 48 h (ICC ≥ 0.96). The highest load achieved among the 4 familiarization sessions was used for analysis in each exercise at baseline.

Dietary intake

Participants were instructed by a well-trained dietitian to complete food records on 3 nonconsecutive days (2 week days and 1 weekend day) in the first and last week of the intervention period. Subjects were given specific instructions regarding the recording of portion sizes and quantities to identify all food and fluid intake, in addition to viewing food models in order to enhance precision. Total dietary energy, protein, carbohydrate, and fat content were calculated by nutrition analysis software (Avanutri Processor Nutrition Software, Rio de Janeiro, Brazil; Version 3.1.4). All the subjects were asked to maintain their normal diet during the entire study period.

Blood pressure and heart rate variability measurements

Resting BP and HRV were measured at baseline and at least 72 h after the end of the intervention period, at the same time of day (morning). Before measurements, the participants were instructed not to carry out any mode of physical activity, and not to ingest alcoholic and caffeinated beverages in the prior 24 h. They were also instructed to empty the bladder before measurements.

Baseline and post intervention BP measurements were performed on 3 non-consecutive days. 3 measurements were taken on each day with a 5-min interval between the measurements. The cuff was placed on the right arm that was positioned on a table, and elevated to a height corresponding to the midpoint of the sternum. The average of the 9 measurements was recorded as the reference value at baseline and after the intervention period. The auscultatory method was used to verify BP, employing a mercury sphygmomanometer (Missouri, São Paulo, Brazil) and a stethoscope (Littmann Classic II, St. Paul, MN, USA). All measurements were taken by the same experienced expert (SBP: ICC = 0.99/ CI = 0.98–0.99; DBP: ICC = 0.97/ CI = 0.95–0.98).

For HRV assessment, R-R interval was obtained using a HR monitor (Polar s810i, Kempele, Finland) validated for this purpose [20]. R-R intervals were recorded during a 10 min time window, while the subjects rested in the seated position. This measurement was taken during 1 of the 3 days of the BP measurement. Data were filtered at about 20 bpm to eliminate possible noises from ectopic beats or errors in the equipment reading [48], and the correction percentage of R-R intervals could not exceed 2 %. This procedure was performed using the Polar Precision Performance software, version 4.03 (Electro Oy, Kempele, Finland). If some error was still visually observed, the adjustment was performed by interpolating the adjacent R-R interval values [9]. In the decomposition of parameters provided by the HRV, the respective R-R interval values were transported to the HRV Analysis Software (The Biomedical Signal Analysis Group, University of Kuopio, Finland).

HRV analysis followed the recommendations of the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology [39]. For the analysis, the 5 intermediate recording minutes of each collected period were used. The time domain analysis included the mean R-R intervals, the mean HR in bpm, the standard deviation of the average R-R intervals (SDNN), and the root mean square of successive differences (RMSSD). For the analysis in the frequency domain, the fast Fourier transformation was used to quantify the low- (LF: 0.04 to 0.15 Hz) and the high-frequency components (HF: 0.15 to 0.4 Hz) of the spectrum, which were expressed in absolute values and normalized units. Additionally, the LF/ HF ratio was calculated as an index of the sympatho-vagal balance [30]. Besides the parameters in the time and the frequency domains, a nonlinear analysis was performed using the Poincaré plot, providing the standard deviation of instantaneous beat-to-beat R-R interval variability (SD1) and the standard deviation of continuous long-term R-R interval variability (SD2). Breathing control was not performed during HRV measurement because it has been shown not to have important effects on HRV assessment [7].

Resistance training intervention

Supervised RT program was performed on 3 nonconsecutive days per week (Monday, Wednesday, and Friday) in the morning and was structured based on valid recommendations for RT in elderly population [2, 3] to improve muscular endurance and strength. Each subject was individually supervised by an experienced instructor during each training session in order to reduce deviations from the study protocol and to ensure subject safety. Participants were initially submitted to 6 sessions of familiarization with the equipment and the exercises, and later to a RT program that lasted 12 weeks.

The RT program was a total body program with 8 exercises performed in the following order: machine bench press (chest), leg extension (quadriceps), wide-grip front lat pulldown (latissimus), leg curl (hamstrings), preacher curl (biceps), seated calf raise (calves), triceps pushdown (triceps), and abdominal crunches (abdominals).

Subjects performed 2 consecutive sets of 10–15 repetitions until moderate fatigue in each exercise or stopped when it began to be difficult [29]. The only exception was the abdominal crunch exercise which was performed on the floor using the subject's bodyweight (20 to 30 repetitions without any additional overload). The participants were instructed to inspire during the eccentric phase and exhale during the concentric phase of the exercise and to maintain the speed of movements at a ratio of 1:2 (concentric and eccentric phases, respectively). Subjects rested for 60- to 90-s between each set and for 2- to 3-min between each exercise.

The instructors adjusted the loads of each exercise according to the subject's ability and improvements in exercise capacity throughout the study in order assure that the subjects were exercising with as much resistance as possible while maintaining proper exercise technique. Progression was planned so that when 15 repetitions were completed for 2 consecutive sets, the weight was increased 2–5 % for the upper limb exercises and 5–10 % for the lower limb exercises [2]. At the end of each session, approximately 5 min were used for stretching the exercised muscles.

Stretching program

Subjects in the CG performed supervised stretching exercises sessions based on the American College of Sports Medicine recommendations [3]. A static stretching program was performed on 2 nonconsecutive days per week during 12 weeks in the morning period. All the training sessions lasted 25–30 min and included stretching exercises that were actively performed (i. e., unassisted stretching) for both the upper and the lower body muscle groups. For each stretching exercise, the muscle was held at the maximal stretched position for 20 s, and this procedure was repeated 2 times. The rest interval between the trials was 15 s and a minimum of 30 s separated the different exercises. Subjects were instructed to maintain their normal level of physical activity and were specifically asked not to start a new exercise regimen during the study period.

Table 1 General characteristics of the sample measured at baseline and after 12 weeks of intervention in the control (CG) and the training (TG) groups.

	TG (n=15)			CG (n=14)		
	Baseline	After 12 wk	ES	Baseline	After 12 wk	ES
age (years)	65.5±5.0		–	66.2±4.1		–
body mass (kg)	57.3±6.5	57.2±6.5	−0.02	61.1±11.7	61.6±12.2	0.04
height (cm)	156.7±5.1	156.5±4.9	–	157.5±7.1	157.6±7.0	–
BMI (kg/m²)	23.9±2.9	24.0±2.6	0.04	25.1±3.4	25.4±3.8	0.08
body fat (%)	39.5±6.3	38.5±6.5	−0.16	41.1±5.5	40.7±5.3	−0.07
fat-free mass (kg)	34.4±3.0	34.9±3.2	0.16	35.7±5.8	36.2±5.9	0.09
fat mass (kg)	22.9±5.5	22.3±5.5	−0.11	25.4±7.2	25.4±7.5	0
machine bench press 1-RM (kg)†‡	26.5±4.6	29.2±5.3*	0.54	29.5±5.6	29.1±6.2	−0.07
leg extension 1-RM (kg)†	24.5±4.1	27.6±3.7*	0.79	25.6±4.6	25.2±4.7	−0.09

BMI=body mass index, ES=effect size. Values are expressed as mean±standard deviation. ‡Data analyzed by ANCOVA. †Significant group×time interaction ($P<0.05$)
*Different from baseline ($P<0.05$)

Table 2 Energy and macronutrient intake in the first and last of the 12 weeks of intervention in the control (CG) and the training (TG) groups.

	TG (n=15)			CG (n=14)		
	Baseline	After 12 wk	ES	Baseline	After 12 wk	ES
energy (kcal/d)	1440±197	1432±179	−0.04	1379±160	1420±159	0.26
carbohydrates (g)	207.1±24.4	203.4±28.2	−0.14	188.6±23.5	203.0±25.4	0.59
protein (g)	63.8±18.9	60.2±18.9	−0.19	59.7±10.3	60.0±10.7	0.03
lipids (g)	41.6±12.9	41.1±12.4	−0.04	46.4±8.9	44.0±8.0	−0.28
carbohydrates (g/kg)	3.7±0.7	3.6±0.8	−0.13	3.1±0.7	3.3±0.9	0.25
protein (g/kg)	1.1±0.3	1.0±0.3	−0.33	0.9±0.3	1.0±0.3	0.33
lipids (g/kg)	0.7±0.2	0.7±0.2	0.00	0.8±0.2	0.7±0.2	−0.50
carbohydrates (%)	58.6±10.5	57.3±8.0	−0.14	52.4±4.1	55.8±4.9	0.75
protein (%)	17.7±4.5	16.8±4.9	−0.19	16.4±1.8	17.0±2.7	0.26
lipids (%)‡	25.6±6.1	25.5±6.1	−0.02	30.2±4.1	27.9±4.0	−0.57

Values are expressed as mean±standard deviation. ‡ Data analyzed by ANCOVA

Statistical analysis

The data were stored and analyzed using the Statistical Package for the Social Sciences (SPSS for Windows Version 17.0). Normality was checked by Shapiro-Wilk's test, and the HRV indexes that were not normally distributed (LF and HF in ms^2) were logarithmically transformed. Baseline differences between groups were assessed with an independent *t*-test. A 2 factor (group×time) mixed design ANOVA with repeated measures on one factor (time) was used for intra- and inter-group comparisons at baseline and after 12 weeks of intervention. When significant differences at baseline between the 2 groups were detected, analysis of covariance (ANCOVA) for repeated measures was used with the baseline values used as a covariate. In variables where sphericity was violated, as indicated by Mauchly's test, the analyses were adjusted using a Greenhouse-Geisser correction. A *post hoc* Fisher's test was used when significant F ratios were found for main or interaction effects. For all the statistical analyses, significance was accepted at $P<0.05$. The differences in magnitudes were calculated from the effect size (ES). An ES of 0.20–0.49 was considered as small, 0.50–0.79 as moderate, and more than 0.80 as large [12]. To calculate the sample size required, an alpha of 95% and power of 75% were adopted. Data are presented in means±SE.

Results

General characteristics of the study participants at baseline and after 12 weeks of intervention are shown in **Table 1**. Body composition did not change in either group during the study. Upper body strength was higher at baseline in the CG than the TG, and ANCOVA showed that upper body strength increased only in the TG ($F=6.34$, $P=0.02$) from the pre- to post-training period. Similar results were observed in lower body strength which only increased in the TG group ($F=36.61$, $P<0.001$). Effect sizes for these increases were moderate (ES=0.54 and 0.79, respectively).

In regard to diet, only relative lipids consumption was significantly different between the groups at baseline. (CG>TG, $P<0.05$). However, ANCOVA indicated no differences between groups for this variable after 12 weeks of intervention. For the other variables related to energy and macronutrient intake, no statistically significant difference ($P>0.05$) was found for intra- or inter-group comparisons (**Table 2**).

Resting SBP, DBP and mean blood pressure (MBP) measured at baseline and after 12 weeks of intervention are shown in **Table 3**. The BP changes for each group from pre- to post-training period are also shown in **Fig. 1**. At baseline, BP values were similar between groups. SBP decreased significantly from pre- to post-training in the TG (−5 mmHg; ES=−0.67, P=0.01), while MBP and DBP did not change in either of the groups throughout the study ($P>0.05$).

The analysis of resting HRV at baseline and after 12 weeks of intervention can be observed in **Table 4**. When analysis was performed in the time domain, R-R interval and HR were higher in the CG than in the TG at the baseline ($P<0.05$). However, ANCOVA revealed no significant difference in these variables between groups after 12 weeks of intervention. Additionally, all the other time domain HRV indexes, as well as the indexes obtained at the frequency domain or by the nonlinear analysis did not change throughout the study for either group ($P>0.05$).

Table 3 Resting systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean blood pressure (MBP) measured at baseline and after 12 weeks of intervention in the control (CG) and the training (TG) groups.

	TG (n = 15)	CG (n = 14)	Effects	F	*P*
SBP (mmHg)			ANOVA		
baseline	125 ± 8	123 ± 9	Group	0.69	0.42
after 12 wk	120 ± 7*	126 ± 8	Time	0.67	0.42
ES	− 0.67	0.35	Interaction	9.02	0.006
DBD (mmHg)			ANOVA		
baseline	81 ± 6	80 ± 6	Group	0.21	0.65
after 12 wk	80 ± 6	82 ± 5	Time	0.23	0.64
ES	− 0.17	0.36	Interaction	1.54	0.23
MBP(mmHg)			ANOVA		
baseline	95 ± 6	95 ± 6	Group	0.46	0.51
after 12 wk	93 ± 6	97 ± 6	Time	0.03	0.87
ES	− 0.33	0.33	Interaction	4.99	0.03

ES = effect size. Values are expressed as mean ± standard deviation. *Different from baseline ($P<0.05$)

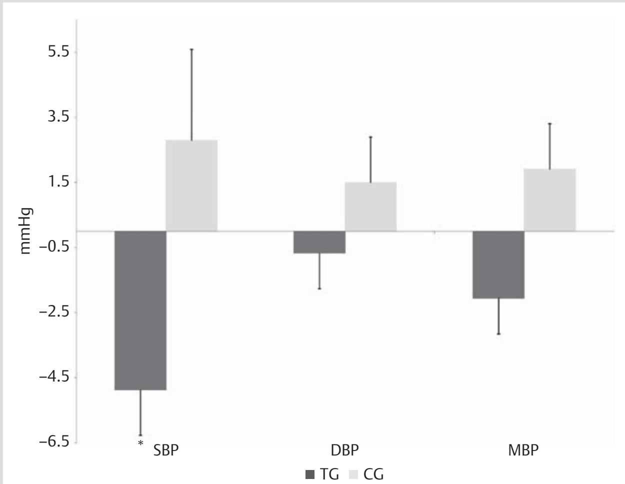

Fig. 1 Mean changes observed for systolic (SBP), diastolic (DBP), and mean blood pressure (MBP) from baseline to 12 weeks of intervention in the control (CG) and the training (TG) groups. *$P<0.05$ vs. CG.

Discussion

The main findings of the present study were that 12 weeks of a supervised RT program increased muscular strength and reduced SBP without affecting DBP and HRV in untrained, non-hypertensive, postmenopausal, elderly women. Therefore, our results confirm the positive effects of RT in the elderly.

Regarding the chronic effect of RT on resting BP, previous studies have reported reductions [10, 34, 38, 40, 41, 46], no changes [14, 18, 43, 44], or even increases [32] in BP after different training regimens and periods, and in different populations. The controversies among previous studies may be related to differences in the characteristics of the samples studied (age, initial BP values, etc.) and the manipulation of several variables that are part of training programs (exercise selection and order, number of series and repetitions, repetition velocity, rest periods between sets and exercises, frequency, among others). In addition, many of these previous studies have methodological problems, such as lack of a control group [14, 38], no control of diet intake [10, 14, 18, 38, 43, 44], poor control of the pre training level, and the absence of an individualized training program [41]. In this sense, the Dietary Approaches to Stop Hypertension (DASH) suggest that changes in diet can provide substantial changes in BP of different individuals [5].

The present study was designed to avoid these limitations. The protocol included a control group and the sample was composed exclusively of sedentary or insufficiently active older women whose eating habits were monitored throughout the study. Prior to testing, subjects were familiarized to the tests to reduce the learning effects of repetition. Finally, the RT program was individualized and followed the guidelines suggested for this population [2, 3].

In the present study, a moderate but significant reduction of about 5 mmHg in SBP was observed in healthy elderly women after 12 weeks of a low to moderate-intensity RT. Comparison of these results with previous investigations conducted with similar populations are interesting. In a previous study conducted with older hypertensive women receiving antihypertensive treatment, SBP reductions observed after 12 weeks of RT were approximately

Table 4 Heart rate variability indexes evaluated in the frequency domain, time domain and nonlinear analysis using the Poincaré plot at baseline and after 12 weeks of intervention in the control (CG) and the training (TG) groups.

	TG (n = 15)			CG (n = 14)		
	Baseline	After 12 wk	ES	Baseline	After 12 wk	ES
Frequency domain						
LF (ms^2)	76 ± 58.7	71.5 ± 51.9	− 0.08	79.9 ± 92.3	58.2 ± 37.9	− 0.31
HF (ms^2)	31.1 ± 23.9	41.1 ± 32.6	0.35	36.2 ± 35.6	21.7 ± 16.3	− 0.52
lnLF (ms^2)	4.0 ± 0.9	4.0 ± 0.8	0	3.7 ± 1.3	3.7 ± 1.0	0
lnHF (ms^2)	3.1 ± 0.9	3.3 ± 1.1	0.20	3.0 ± 0.9	2.8 ± 0.7	− 0.24
LF nu	69.52 ± 14.8	64.01 ± 18.5	− 0.35	62.81 ± 18.6	67.99 ± 15.6	0.30
HF nu	30.48 ± 14.8	35.97 ± 18.5	0.29	37.19 ± 18.6	32.01 ± 15.6	− 0.30
LF/HF	3.39 ± 2.9	3.17 ± 3.6	− 0.04	2.77 ± 2.6	3.11 ± 2.2	0.14
time domain						
R-R interval (ms) ‡	820 ± 90	850 ± 100	0.32	770 ± 60	750 ± 70	− 0.31
SDNN (ms)	20 ± 7	20 ± 8	0	30 ± 21	30 ± 45	0
HR (bpm) ‡	73.86 ± 8.0	71.89 ± 8.8	− 0.23	78.37 ± 3.1	81.14 ± 7.9	0.46
RMSSD (ms)	16.19 ± 6.5	17.17 ± 7.4	− 0.003	18.8 ± 18.7	13.36 ± 7.5	− 0.38
nonlinear analysis						
SD1 (ms)	11.69 ± 4.6	12.44 ± 5.3	0.15	13.71 ± 13.7	9.72 ± 5.4	− 0.38
SD2 (ms)	39.28 ± 14.5	42.09 ± 15.9	0.19	40.96 ± 23.7	32.94 ± 8.1	− 0.45

ES = effect size, LF = low-frequency, HF = high-frequency, SDNN = standard deviation of the average R-R intervals, HR = heart rate, RMSSD = root mean square of successive differences, SD1 = dispersion of the points perpendicular to the line of identity, SD2 = dispersion along the line of identity. Values are expressed as mean ± standard deviation. ‡ Data analyzed by ANCOVA. Absolute values of LF and HF (ms^2) were logarithmically transformed to correct the skewness of distribution

10.5 mmHg [41]. The greater magnitude of response compared to those obtained in our study might be due to differences in the RT protocol utilized and the pre-existing hypertensive condition. There is some evidence that reductions in BP after physical training are directly related to the initial BP levels [1]. Thus, hypertensive individuals may respond with greater decreases in BP after an exercise program compared to non-hypertensive ones, which is of particular clinical interest. Furthermore, the fact that individuals were taking antihypertensive medications may have contributed to a greater reduction in BP.

In some previous studies, the BP decrease promoted by RT was attributed to the reduction in body mass [34, 37]. However, in the present study, the SBP decrease was not accompanied by changes in body composition, indicating that chronic hypotensive effects of RT occurs regardless of body mass changes.

Our study results are in opposition to the idea that moderate to high-intensity RT increases arterial stiffness [18], which could be dangerous to the cardiovascular system, especially in elderly individuals who already present structural changes in arteries and may be less susceptible to the benefits of RT on BP [37]. Although the artery structure was not evaluated in the present study, SBP decreased after 12 weeks of RT which suggests that stiffness was unchanged or even decreased, and shows that elderly subjects may benefit from BP reduction after RT. Relatively similar results had been reported in other studies [10, 38, 41].

The physiological mechanisms responsible for the decrease in resting BP after the RT program were not within the scope of the present study and are not fully established in the literature. However, this decrease may be a multifactorial phenomenon. Some researchers have offered the hypothesis that the exposure to moderate/ high training loads in each RT session and, consequently, to the high BP peaks achieved during exercise may be the stimulus for a baroreflex adaptation [44, 46], leading to a reduction in muscle sympathetic nerve activity and, consequently, lowering peripheral vascular resistance [46] and BP. In contrast, other researchers have refuted this previous hypothesis because they failed to observe any changes in muscle sympathetic activity or in plasma norepinephrine concentrations after different RT periods [10, 14], even when resting BP was reduced by training [10].

In the present study, HRV was not changed after 12 weeks of RT. These results are in accordance with other studies involving young [15], adult [43], or elderly [19] individuals which suggest that RT can improve muscular strength, without promoting a reduction in HRV. A possible explanation for the maintenance of HRV after training may be the characteristic of the training protocol. The short period in which the subject was exercising in each RT session probably was not sufficient to promote autonomic changes in the sample investigated, although it was structured according to RT recommendations for elderly individuals [2, 3, 29]. It is speculated that resting HRV modifications are observed specially after training programs composed of sessions of longer duration and with aerobic energy production predominance. However, this hypothesis has yet to be further investigated.

In contrast to this explanation, Taylor et al. [40] observed positive changes in HRV indexes, such as a reduction of sympathovagal balance by submitting hypertensive elderly individuals to an isometric training program with a shorter duration than the 1 employed in the present study. A possible explanation is that an isometric stimulus produces a greater pressure load leading to a faster baroreflex adaptation. On the other hand, Melo et al. [27] observed hazardous effects after 12 weeks of RT in elderly men, with a decrease in parasympathetic and an increase in sympathetic activity, despite observing a decrease in SBP of approximately 6 mmHg (similar to the current study BP result). These authors employed an eccentric training program which may explain the differences compared to the present results. In regard to the mechanisms, Melo et al. [27] speculated that high BP values reached during the RT sessions, together with decreased beta-adrenergic responses observed with advancing age, can increase sympathetic modulation. In this sense perhaps aging reduces the HRV “trainability”, decreasing its sensitivity to training [19]. Indeed, aging has been shown to reduce vagal activity to the heart, decreasing HRV, regardless the changes in arteries structure [27], and some authors suggest that aging may reduce HRV sensitivity to training adaptations [19]. Based on the previous discussion, it is possible to suppose that the effects of RT on HRV may depend on the kind of RT and the population studied, and these differences should be further investigated.

It is also possible that no autonomic adaptations were detected in the current study because of the protocol employed to record HRV. Only short term HRV was assessed in the present study, and other durations of the recordings, such as 24-h HRV could have detected an autonomic adaptation, as shown in a recent study [8] with the same technology (Polar HR monitors) used in the current study. Moreover, some autonomic challenges (e. g. orthostatic stress) [23] and other body positions during recordings [49] may be more sensitive for detecting autonomic adaptations. However, Perini et al. [31] found no differences in HRV indexes response to aerobic training when measurement were taking in a supine or seated position. These aspects should be further investigated in the future.

Another possible limitation to the current study may be that a control group without any intervention was not included in the present study. However, the stretching group serves as a control because it assessed the placebo effect of feeling of being treated, and the absence of changes in this group throughout the study suggests that it was a good control. Nevertheless, we have to consider a possible effect of the stretching program on HRV if other more sensitive HRV methods had been employed. Santaella et al. [35], for example, observed improvements on HRV in elderly subjects after a 4-month Yoga program. Yet, another study showed that a stretching training can increase HRV in young athletes [28].

The results of our study suggest that a supervised RT program for 12 weeks can improve muscular strength and reduce the SBP without affecting DBP and HRV in untrained, non-hypertensive, postmenopausal elderly women. Thus, this approach appears to be a good hypertension prevention strategy and an excellent way to promote or maintain a good quality of life. It is important to highlight that RT programs may provide greater BP reductions in hypertensive individuals [1] and that a reduction of only 5 mmHg in BP may reduce by 40 % the risk of strokes and by 15 % the risk of an acute heart attack [13]. Therefore, the findings of this study seem promising. It is suggested that the impact of different types of training on BP and HRV, such as concurrent training, and the mechanisms responsible for these cardiac and autonomic adaptations should be investigated in future studies.

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