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ORIGINAL RESEARCH

Resistance exercise with different volumes: blood pressure response and forearm blood flow in the hypertensive elderly

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Background: The purpose of this study was to evaluate the effect of two sessions of resistance exercise with different volumes on post-exercise hypotension, forearm blood flow, and forearm vascular resistance in hypertensive elderly subjects.

Methods: The study was conducted with ten hypertensive elderly (65±3 years, 28.7±3 kg/m^2) subjected to three experimental sessions, ie, a control session, exercise with a set (S1), and exercise with three sets (S3). For each session, the subjects were evaluated before and after intervention. In the pre-intervention period, blood pressure, forearm blood flow, and forearm vascular resistance were measured after 10 minutes of rest in the supine position. Thereafter, the subjects were taken to the gym to perform their exercise sessions or remained at rest during the same time period. Both S1 and S3 comprised a set of ten repetitions of ten exercises, with an interval of 90 seconds between exercises. Subsequently, the measurements were again performed at 10, 30, 50, 70, and 90 minutes of recovery (post-intervention) in the supine position.

Results: Post-exercise hypotension was greater in S3 than in S1 (systolic blood pressure, −26.5±4.2 mmHg versus −17.9±4.7 mmHg; diastolic blood pressure, −13.8±4.9 mmHg versus −7.7±5 mmHg, $P<0.05$). Similarly, forearm blood flow and forearm vascular resistance changed significantly in both sessions with an increase and decrease, respectively, that was more evident in S3 than in S1 ($P<0.05$).

Conclusion: Resistance exercises with higher volume were more effective in causing post-exercise hypotension, being accompanied by an increase in forearm blood flow and a reduction of forearm vascular resistance.

Keywords: blood pressure, resistance exercise, elderly, hypertension, post-exercise hypotension

Introduction

Hypertension is a multifactorial and multicausal syndrome characterized by high blood pressure (BP) levels, usually associated with metabolic, hormonal, and structural disorders.[1] Mild hypertension is defined as a BP level of 140–159 mmHg systolic and/or 90–99 mmHg diastolic.[2] This condition augments the risk of vascular events, such as coronary heart disease, stroke, heart failure, peripheral artery disease, chronic kidney disease, and dementia.[3] Approximately one billion individuals worldwide are affected by hypertension, and these numbers are increasing with time.[3,4]

Hypertensive individuals have decreased blood flow and vascular conductance at rest, which reduces their vasodilator reserve, with a consequent alteration of vasodilator responses.[5] Age-related endothelial dysfunction, vascular remodeling, and increased arterial stiffness contribute to the increased prevalence of hypertension among

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the elderly.[6] The treatment of systemic arterial hypertension includes pharmacological therapy and lifestyle changes, such as re-education regarding nutritional habits.[5] Concomitantly, it is evident in the literature that regular physical activity can prevent these undesirable changes.[7]

The ability of exercise to reduce BP is well established.[8] Several studies have been conducted to elucidate the relationship between type of exercise and magnitude of the hypotensive response after exercise. Although without consensus, most studies show that aerobic exercise promotes greater BP reductions compared with resistance exercise. The Seventh Report of the Joint National Committee[5] recommends aerobic exercise as a form of BP control. One of the possible mechanisms of this reduction would be an improvement in the vasodilator response to a longer exposure to aerobic exercise.[9] However, recent studies indicate that, according to the methodology used, the hypotensive effect of resistance exercise can be in the same proportion to that of aerobic exercise.[1,10–14]

Several agencies have procedures that guide the prescription of exercise for the elderly. In these documents, much attention is given to cardiovascular and oesteoarticular safety, particularly regarding the intensity of training. The American College of Sports and Medicine[4] suggests that resistance exercise should be prescribed with moderate loads (60% one repetition maximum) for hypertensive patients. The American Heart Association has proposed that healthy older adults could perform exercises at intensities above 60% one repetition maximum.[15] Additionally, cardiac patients, regardless of age, could perform exercises at lower intensities. However, no consideration is given to the best prescription volume of exercise to promote post-exercise hypotension in the elderly. This is important since cardiovascular responses in multiple series can be higher than with single series.[16]

Although the research carried out so far has investigated the effects of resistance exercise on BP, there are obvious gaps regarding the best prescription of resistance exercise, mainly concerning the population involved and which mechanisms are involved in post-exercise responses, because of the diversity and variations in the research protocols with respect to intensity, number of sets, intervals, and method of BP measurement.[1,10–13,17]

To date, few studies have evaluated the hemodynamic effects of resistance training with respect to vasodilator function and post-exercise hypotension in hypertensive elderly individuals.[14,18] Of these, only one has investigated the effects of different training volumes in post-exercise hypotension.[14] However, in that study, only BP was used as a hemodynamic parameter. In addition, the protocol used was composed of just four exercises, reducing the external validity of the study, since in practical context it tends to use more variety and quantity of exercises. Thus, investigation of the mechanisms by which different exercise volumes affect the BP response in the hypertensive elderly patient is still a pertinent and relevant gap in the research.

We hypothesized that resistance exercises with higher volumes would promote better BP and vascular responses in the hypertensive elderly, eg, post-exercise hypotension and forearm blood flow. Given the above, the purpose of this study was to investigate BP, forearm blood flow, and forearm vascular resistance in hypertensive elderly patients after a session of resistance exercise with different volumes.

Materials and methods

Subjects

This study was conducted with ten elderly patients (including six women) with mild hypertension according to the classification proposed by the American College of Sports and Medicine.[4] They were all physically active and had participated regularly for at least 3 months in a program of resistance exercise in the gym at the Federal University of Paraíba. In order to participate in the study, they needed to be aged 59–69 years, performing physical exercise three times or more per week, with hypertension as their only cardiometabolic disease. All were users of hypertensive medications, but these included only angiotensin-converting enzyme inhibitors and diuretics. The subject characteristics are shown in Table 1.

All participants were informed about the procedures that would be used for data collection and signed consent pursuant to resolution 196/96 National Health of Brazil for human experiments prior to their participation. All agreed to

Table 1 Anthropometric, biochemical, and metabolic characteristics

	Hypertensive (n=10)
Age (years)	65.5±3
BMI (kg/m²)	28.7±3
Glucose (mg/dL)	99±7
Triglycerides (mg/dL)	145±25
Cholesterol (mg/dL)	190±15
HDL (mg/dL)	50±5
LDL (mg/dL)	118±16
Drugs	Diuretics (n=10)
	IACE (n=10)

Note: Data are presented as mean ± standard deviation.
Abbreviations: BMI, body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein; IACE, inhibitor of angiotensin converting enzyme.

participate in the methodological procedures proposed in the research, approved by the ethics committee of the Center for Health Sciences UFPB under protocol number 135/10.

Familiarization session and maximum load test

Before the experimental sessions, the subjects underwent a familiarization session (a series of ten repetitions of each exercise with the minimum machine weight allowed). Three days later, they underwent a one repetition maximum test for leg extension, front pulley, leg 45, fly, knee flexion, low row, adductor, triceps, plantar flexion in the leg 45, and biceps following the protocol.[19] Seven days later, we performed a retest to confirm the validity of our previous results. The maximum load was estimated after three attempts at each exercise and with a minimum rest period of 3 minutes between each attempt. After 48 hours, a retest was performed to obtain the greatest workload. Reliability was considered to be good when a difference of 5% was found between the tests. We found correlations of 0.543–0.951 between the results of the tests used for all exercises.

Experimental sessions

The subjects underwent three experimental sessions, ie, a control session, a set of exercises with 50% of one repetition maximum (S1), and exercises with three sets at 50% one repetition maximum (S3), always performed between 7 am and 9 am with a break of at least 7 days. The order was determined individually and randomly using the Research Randomizer website (www.randomizer.org), so that each subject had his or her own order in which to carry out the three study sessions. Before the study, they were instructed to avoid physical activity 48 hours before the experimental sessions.

For each session, the subjects were evaluated before and after intervention. In the pre-intervention period, BP and forearm blood flow were recorded at rest in the supine position. The subjects were later taken to the gym, where they performed the exercise sessions (S1 and S3) or control session. The latter was performed using each item of equipment, during the same time of the exercise sessions. Both S1 and S3 followed the Pescatello et al[4] protocol for variables such as intensity, number of repetitions, time interval, and number of exercises, differing only in the number of series. Thus, the individual subjects performed one or three sets of ten repetitions of ten exercises mentioned above, with an interval of 90 seconds between exercises for the load of 50% one repetition maximum. During the execution of the sessions, the Valsalva maneuver was constantly discouraged, without any stimulus to motivate the subjects. In sequence, they returned to the laboratory for the post-intervention period, where they were placed in the supine position for the forearm blood flow and BP measurements, performed five times over 90 minutes of recovery.

Measurements

Blood pressure

BP measurements were performed at every heartbeat via photoplethysmography using the Finometer PRO (Finapress Medical Systems BV, Amsterdam, the Netherlands); the measurement was obtained by placing the cuff on the middle finger of the dominant hand. Each subject was connected to the Finometer device, and BP was recorded continuously for a period of 10 minutes. After a recording period of 2 minutes, the Finometer offers the option to perform a return-to-flow systolic calibration (this is an individual patient level adjustment, which calibrates the upper arm pressure of each specific subject with his or her finger pressure).[20] Highest precision in BP readings is obtained only after this calibration in the dominant upper arm, always before exercise sessions. Mean systolic and diastolic BPs were determined from the mean BP over 10 minutes of recording. The waveform generated by the equipment was acquired on a computer at a sampling frequency of 500 Hz using a data acquisition system (WinDaq DI-720; Dataq Instruments Inc, Akron, OH, USA).

Heart rate

An electrocardiogram was used to determine heart rate. Three electrodes were placed in the patient's chest, in DII. The acquisition and visualization of the electrocardiographic signal was obtained by WinDaq Acquisition software.

Forearm blood flow

The forearm blood flow was assessed by venous occlusion plethysmography. For this evaluation, two cuffs were placed on the nondominant arm, one around the wrist and the other on the upper arm, which were connected to the plethysmograph (AG 201, Hokanson, Bellevue, WA, USA). The cuff placed around the wrist was inflated to suprasystolic mode a minute before starting the measurements. At 10 seconds, the arm cuff was inflated above the venous pressure for 7–8 seconds. Changes in the circumference of the forearm were perceived by a silastic tube of mercury, placed two inches away from the humerus-radial and connected to the plethysmograph. We elected to measure blood flow in the forearm, since Endo et al[21] mention in their paper that post-exercise hypotension is directly associated with increased total vascular conductance.

Forearm vascular resistance

Forearm vascular resistance was calculated by determining the ratio between mean BP and forearm blood flow.

Data analysis

The normality of the data was checked by the Shapiro–Wilk test. Changes in BP values were calculated by the difference between the values measured before and after intervention. To analyze the variables over three time points (before × S1 × S3), we used two-way analysis of variance for repeated measures. The post hoc Newman–Keuls test was used to locate the differences in analysis when the observed value was $P<0.05$. For all analyses, the level of significance was $P<0.05$. The data are presented as the mean and standard deviation. The statistical analysis was performed using the statistical program Statistica for Windows (version 4.3, StatSoft Inc, Tulsa, OK, USA).

Results

All subjects completed the study without any adverse events. In all experimental sessions, subjects presented similar basal values for BP, heart rate, and forearm blood flow, with no statistically significant differences identified between the three sessions. These are described in Table 2.

The BP responses after three experimental sessions are shown in Figure 1. Procedures S1 and S3 were able to promote a significant reduction in systolic BP, diastolic BP, and mean BP at 90 minutes post-intervention compared with both the control session and the baseline values for S1 and S3. Moreover, the reduction in BP was higher in the recovery period after S3 in comparison with S1. This behavior was observed for systolic BP, diastolic BP, and mean BP ($P<0.05$).

Forearm blood flow showed a significant increase in exercise sessions at all post-intervention measurements. Comparing the exercise protocols, it was found that forearm blood flow was always higher in S3 ($P<0.05$). Confirming the forearm blood flow responses, there was a significant reduction in both exercise sessions at all times regarding forearm vascular resistance. When comparing the two protocols of exercise, we could observe that the forearm vascular resistance values were always lower in S3 at all post-exercise time points ($P<0.05$; Figure 2).

Table 2 Hemodynamic characteristics of subjects

Baseline	CS	S1	S3	P
SBP (mmHg)	145±3	147±4	146±3	0.410
DBP (mmHg)	92±4	93±4	91±3	0.606
MBP (mmHg)	117±3	115±4	116±5	0.677
HR (bpm)	85±4	80±4	82±4	0.750
FBF (mL/kg/min)	2.87±0.42	3.11±0.57	3.27±0.35	0.314

Note: Data are presented as mean ± standard deviation.
Abbreviations: CS, control session; S1, exercise with one set; S3, exercise with three sets; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; MBP, mean blood pressure; FBF, forearm blood flow.

Discussion

The data from this study confirm the premise that resistance exercise is able to promote post-exercise hypotension in hypertensive elderly people, and demonstrate that there are differences regarding the exercise volume, since the magnitude of post-exercise hypotension was significantly greater for exercises with higher volume. Moreover, this study contributes to the literature regarding the related mechanisms of post-exercise hypotension in the hypertensive elderly, as it was observed that the hypotension was accompanied by an improvement in forearm blood flow and forearm vascular resistance during the recovery period.

In spite of resistance exercise gaining increasing notoriety for its ability to promote reduction of BP after exercise, to make assertions about the best prescription for this type of exercise in promoting post-exercise hypotension is still somewhat rash.[22] This stems from the wide variety of experimental designs reported in the literature on differences in training models (conventional or circuit), time interval (30–120 seconds), intensity (medium to high), number of repetitions (8–20), number of exercises, analytical methods for measuring BP (clinic, ambulatory) and sample (young, middle-aged adults, elderly, healthy, and/or hypertensive).[14,18,23–26] Thus, generalizations are inappropriate.

Although there have been other studies using the elderly as the sample population, most of them were conducted with healthy subjects and in isometric or isokinetic resistance training.[12,17,27] Use of aerobic exercises in the context of post-exercise hypotension is more common,[1,12,13,17] with few studies using resistance training in the elderly.[10,11,13] Only Polito and Farinatti investigated the volume of exercise in post-exercise hypotension, but in young individuals.[28] In this way, our findings represent an important contribution to explaining how resistance exercise may benefit the hypertensive elderly.

Regarding the acute responses to resistance exercise, the literature shows that BP is the hemodynamic variable most often investigated, both in clinic and ambulatory fashion. Some studies show that acute bouts of resistance exercise can promote significant reductions in BP in both healthy subjects[18,29–31] and hypertensives.[1,23,24,30,32] Of the studies in

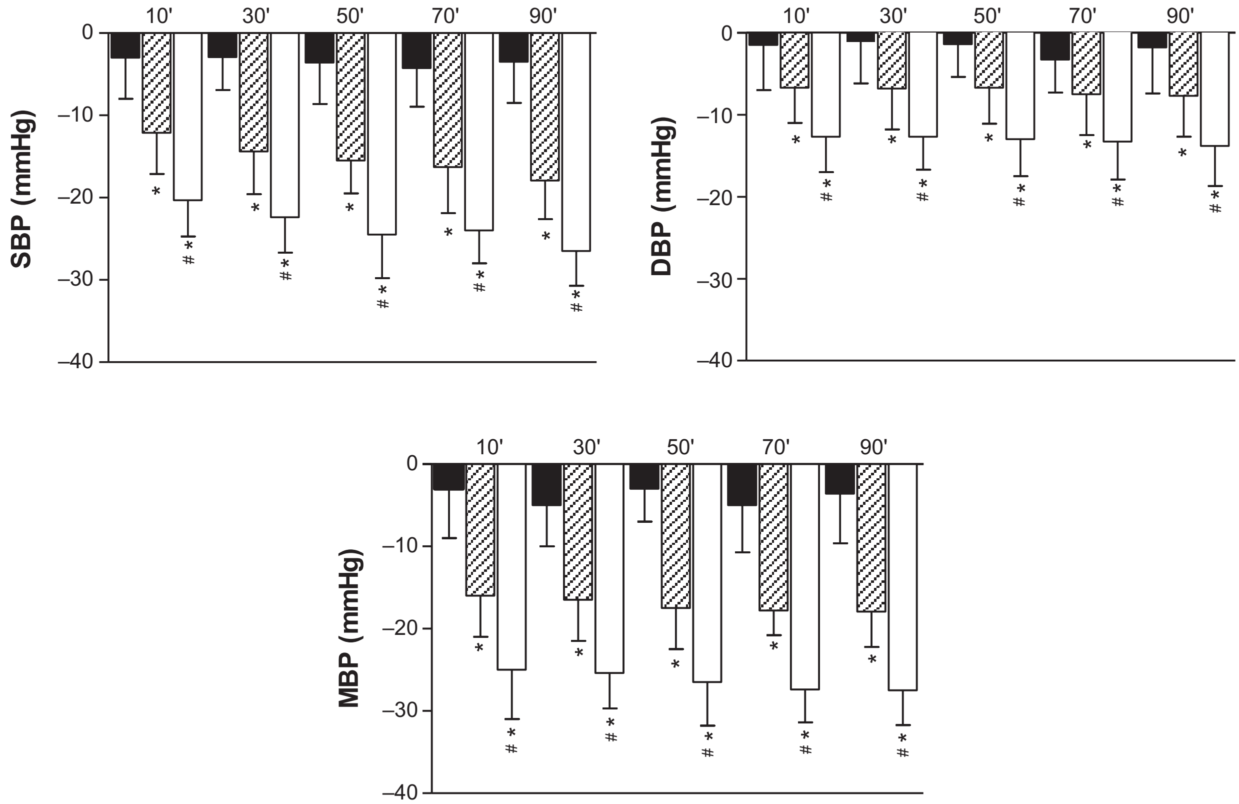

Figure 1 Post-exercise hypotension in control session (black), with one set (S1) and three sets (S3). Data are presented as mean and standard deviation.
Notes: *Means $P<0.05$ compared with the control session and #means $P<0.05$ compared with S1.
Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; MBP, mean blood pressure.

hypertensive subjects, the values obtained range from –2 to –13 mmHg for systolic BP and from –2 to –7.9 mmHg for diastolic BP.[1,30,32]

Our study has found even greater hypotension values, even when the exercise sessions were undertaken with a single set, with systolic BP and diastolic BP values of –17.9±4.7 mmHg and –7.7±5.0 mmHg, respectively. Furthermore, when exercise sessions were conducted with three sets, these values were even greater, ie, –26.5±4.2 mmHg for systolic BP and –13.8±4.9 mmHg for diastolic BP. Although these values are quite pronounced when compared with the literature, we found similar values of post-exercise hypotension for the S1 protocol in other studies we performed in our laboratory, also with hypertensive elderly patients, with three sets and in similar exercise protocol.[27,33,34]

The fact that our study was carried out in a university fitness center with training programs targeted exclusively for the elderly population enabled us to provide data for this population of hypertensives. We value the safety of patients, following protocols already used in another study,[27] respecting variables such as intensity, volume, and interval. This demonstrates that our work has external validity, since it shows that even trained people (a population in which it is more difficult to achieve hypotensive responses due to physiological adaptations[35]) can benefit from regular training (since it is logical for this segment of the population to be engaged in a training program).

The mechanisms behind this somewhat pronounced post-exercise hypotension need investigation. It is possible that different isolated or combined physiological pathways have contributed to such a phenomenon. Among them, there is already enough evidence that microvascular changes,[36] reduced cardiac output resulting from decreased stroke volume,[30] and blood lactate concentration[37] are related to post-exercise hypotension. Moreover, it is known that neural parameters, such as reduced sympathetic activation, and humoral parameters, such as greater bioavailability of nitric oxide[12] and antioxidant compounds, are well established mechanisms involved in post-exercise hypotension.[1]

Another possible explanation is proposed by Melo et al.[24] These authors observed that resistance exercises were able to promote reductions in both systolic and diastolic BP in hypertensive patients using antihypertensive drugs, indicating possible synergistic effects. Our study did not investigate all of the physiological parameters described above. Therefore, the data from our study stimulate a

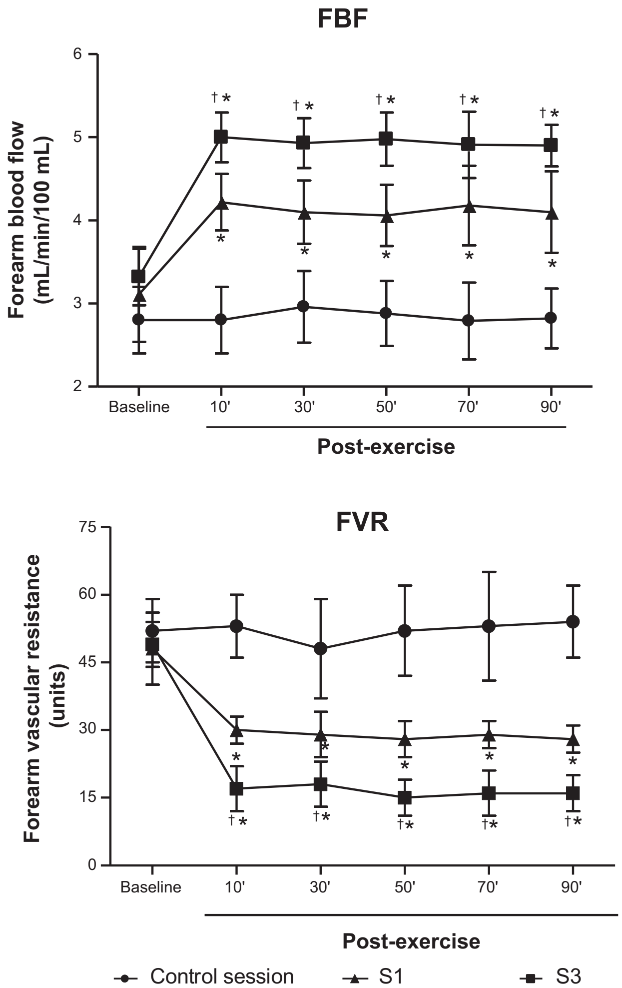

Figure 2 Behavior of the forearm blood flow (FBF) and forearm vascular resistance (FVR) in the control and resistance exercise sessions (S1 and S3). Data are presented as mean and standard deviation.
Notes: *Means $P<0.05$ compared with the control session and †means $P<0.05$ compared with the session S1.

line of investigation to determine the pathways by which exercise volume may act on post-exercise hypotension in the hypertensive elderly.

It is known that post-exercise hypotension does not differ between the sexes.[38–40] However, it seems that the mechanisms by which it occurs are different.[40] In men, post-exercise hypotension is more related to decreased cardiac output due to decreased stroke volume (central hemodynamic mechanisms).[38] Women, in contrast, have lower systemic vascular resistance (peripheral mechanisms).[39] This response in women may be related to estrogen, since in ovariectomized women this improvement disappears.[41] Several studies have investigated the mechanisms of post-exercise hypotension in aerobic exercise.[1,12,13,17] Regarding resistance exercise, only one study has been conducted,[40] noting the differences mentioned above. However, it is important to note that these differences were observed in young, healthy, normotensive patients, with limited ability to extrapolate to other populations. Whether hypertensives of different sexes have different mechanisms for post-exercise hypotension is something the previous literature is not able to answer. Thus, it is suggested to conduct studies that address the mechanisms of post-exercise hypotension in hypertensive elderly men and women.

Unlike the present study, there is inconsistency in diastolic BP reduction in other studies, in specific post-exercise recovery moments.[1,14,30,42] Only Melo et al[24] observed similar responses to our work. As stated by Fisher,[23] these contrasting results can be attributed to different baseline BP in the studies, since different population groups (normotensive and varying degrees of hypertension) respond differently to exercise.[43] Another interesting argument to elucidate this question is provided by Gotshall et al[16] affirming that the subject's position during the recovery period influences the pressure responses. The orthostatic stress imposed in the seated position, often used in various trials, could reduce venous return and the cardiopulmonary reflex, resulting in increased peripheral vascular resistance and consequently diastolic BP.

The increase in forearm blood flow and reduction in forearm vascular resistance after the sessions of resistance exercise in this study corroborate the findings of Kawano et al,[36] Moraes et al,[35] and Heffernan et al.[29] The moderate intensity and high volume of this exercise protocol promoted improvement in vasodilator response, as measured by blood flow. A study by Tanimoto and Ishii[46] demonstrated that prolonged resistance exercise with low intensity, slow movements, and tonic force generation in muscle induced muscle hypertrophy via the hypoxic environment, and could result in angiogenesis. Thus, improvements in these vascular parameters could be associated with resistance exercise-induced angiogenesis.

The present study has some limitations. First, blood flow was observed in the arm, whereas the leg was exercised. It is necessary to investigate whether the peripheral blood flow in the exercise muscle is affected. Second, we did not use a normotensive elderly sample to verify if the quite pronounced post-exercise hypotension observed was because of the high BP of the subjects or just factors related to age. Moreover, the small sample and study population could limit our findings to some degree. Extrapolation to other conditions should be made with caution. Thus, it is suggested to conduct studies that complement these issues (method of BP measurement, normotensive control group, and sample size).

In this way, we can conclude that sessions of resistance exercise with different volumes are able to promote significant post-exercise hypotension and increase peripheral vasodilatation in elderly hypertensive patients, with these effects being more pronounced in sessions with higher volume. This study demonstrates that resistance exercise with higher volume is able to promote post-exercise hypotension in the hypertensive elderly. In addition, this protocol may be helpful for professionals who want to guarantee cardiovascular safety and strength gains in a hypertensive elderly population.

Disclosure

The authors report no conflicts of interest in this work.

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