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Original Article (short paper)

Twenty minutes of post-exercise hypotension are enough to predict chronic blood pressure reduction induced by resistance training in older women

Erick H. P. Eches[1*], Alex S. Ribeiro[1,2], Aline M. Gerage[3], Crisieli M. Tomeleri[1], Mariana F. Souza[4], Matheus A. Nascimento[5], Edilaine F. Cavalcante[1], Durcelina Schiavoni[1], Diego G. D. Christofaro[6], André Luiz D. Gurjão[4], Jerry L. Mayhew[7], Edilson S. Cyrino[1]

[1] Universidade Estadual de Londrina, UEL, Londrina, PR, Brazil; [2]Universidade do norte do Paraná, UNOPAR, Londrina, PR, Brazil; [3]Universidade Federal de Santa Catarina, UFSC, Florianópolis, SC, Brazil ;[4]Universidade Federal do Vale do São Francisco, UNIVASF, Petrolina, PE, Brazil ;[5]Universidade Estadual do Paraná, UNESPAR, Paranavaí, PR, Brazil;[6]Universidade Estadual Paulista, UNESP, Presidente Prudente, SP, Brazil; [7]Exercise Science Program, Truman State University, Kirksville, Missouri, USA

Abstract — Aim: This study investigated the correlation between post-exercise hypotension (PEH) and chronic blood pressure (BP) reduction in older women after a resistance training (RT) program. **Methods:** Twenty-five older women (≥60 years) performed a RT program for 8 weeks, 3x/week consisting of 3 sets of 8-12 repetitions maximum in 8 exercises. Acute and chronic BP measurements were performed using automatic equipment, in which acute BP was measured before and after 10, 20, 30, 40, 50 and 60 min following the sixth exercise session, while chronic BP was measured pre and post-training. **Results**: Significant decrease for systolic blood pressure (SBP) was observed after the intervention period, however, the diastolic blood pressure (DBP) did not change. To acute changes in BP, SBP decreased at all times after a single RT session, while DBP increased after 40 min. The reduction for SBP after a single RT session at baseline showed positive and significant correlations with the reductions in basal SBP observed after the 8 weeks of RT, the strongest correlations were observed at 20 min. A linear relationship between the magnitude of change in chronic SBP and the 20 min for acute SBP, and 30 min for acute DBP of post-exercise was observed. **Conclusion:** The results suggest that acute BP lowering after RT session is a reliable predictor of chronic BP response to exercise training, and 20 min of resting, after RT training, is enough to indicate chronic response of BP as this measure was highly associated with chronic BP lowering in older women.

Keywords: aging, strength training, systolic blood pressure, diastolic blood pressure, chronic exercise.

Introduction

Aging is associated with several structural and functional changes in the cardiovascular system that increase the risk of chronic diseases development, such as systemic arterial hypertension[1]. Physical exercise has been recommended as a non-pharmacological strategy for management of hypertension[2]. Among the different modalities of exercise, aerobic training is universally recommended for generating greater adaptations and lowering blood pressure[3,4]. On the other hand, resistance training (RT) has been detached for being a safe and efficient strategy with low cardiovascular risk that induce chronic decreases in systolic blood pressure (SBP)[5] and diastolic blood pressure (DBP)[6].

Recent evidences have shown a significant relationship between the acute post-exercise hypotension (PEH) characterized by the fall of blood pressure (BP) below resting levels and the magnitude of chronic decrease in resting BP following aerobic exercises[3,4] and RT programs in young adults[7]. However, the mechanism by which RT induces adaptations is different from that of aerobic exercises[2]. In addition, because the differences between young and older individuals in the cardiovascular system function[8], it seems important to determine the optimal level of RT that might aid in the management of hypertension in older individuals who naturally have a higher cardiovascular risk than younger subjects. Moreover, considering that PEH presents different magnitudes over time, determining post-exercise time-points with higher correlations with SBP might provide helpful information for the professionals who prescribe exercise.

Therefore, the purpose of the present study was to verify the correlation between PEH and the chronic BP reduction in older women after a RT program. Our hypothesis was that the acute PEH would be positively correlated with chronic decrease in resting BP induced by RT.

Methods

Participants

Twenty-five older women participated in this study. Participant recruitment was carried out through newspaper and radio advertisings, and home delivery of leaflets in the central area and residential neighborhoods. All participants completed health history and physical activity questionnaires and met the following inclusion criteria: 60 years old or more, normotensive or hypertensive controlled by medications, may or may not have diabetes or dyslipidemia; physically independent, free from cardiac or orthopedic dysfunction, not receiving hormonal replacement therapy, and not performing any regular physical exercise for more than once a week over the six months preceding the beginning of the study. Participants passed a diagnostic graded exercise stress test with 12-lead electrocardiogram reviewed by a cardiologist and were released with no restrictions for participation in this study. Adherence to the program was satisfactory, with all subjects participating in > 85% of the total sessions. Informed consent was obtained from all individual participants included in the study after a detailed description of study procedures was provided. This investigation was conducted according to the Declaration of Helsinki, and was approved by the local University Ethics Committee. (09167).

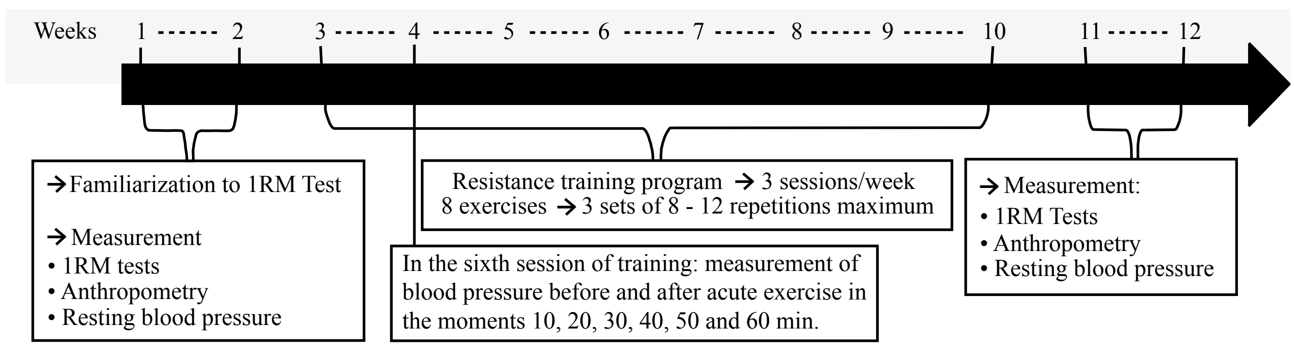
Experimental design

The investigation was carried out over a period of 12 weeks, with 8 weeks dedicated to the RT program, and 4 weeks used for measurements. Anthropometric characteristics, one repetition maximum tests (1RM), and resting BP pressure measurements were performed at pre-training (weeks 1-2) and post-training (weeks 11-12). Supervised RT was performed between weeks 3-10. The acute BP measurements were performed after the sixth training session, which allowed the participants to be familiar with the exercises routine before the acute measurement. Acute BP measurements were performed before and after 10, 20, 30, 40, 50 and 60 min of the session end. Figure 1 shows the experimental design of the study.

Anthropometry

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Balmak, Laboratory Equipment Labstore, Curitiba, PR, Brazil), with the participants wearing light workout clothing and no shoes. Height was measured with a stadiometer attached on the scale to the nearest 0.1 cm with participants standing without shoes. Body mass index was calculated as body mass in kilograms divided by the square of height in meters.

Figure 1. Graphical description of study timeline. 1RM = one repetition maximum.



Blood pressure

Both acute and chronic BP measurements were always performed using an automatic equipment (Omron HEM-742INT model, Omron Corporation, Kyoto, Kansai, Japan). To analyze the chronic effects of RT on resting BP, the participants attended the laboratory on three different days before and after the RT period. At each visit the participants remained in a seated position at rest for five minutes. Several BP measurements were taken until three measurements with no more a 4-mmHg difference among them was identified, and the median of these three measurements was considered the BP score of each day. The average of the three visits was registered as the participants' final BP score. The procedures followed the recommendations of the VI Brazilian Guidelines on Hypertension[9]. All measurements were performed in a temperature-controlled room (~21º to 24º).

For the acute measurements, BP evaluation was performed before the RT session (in triplicate after five minutes of seated rest), and at 10 min, 20 min, 30 min, 40 min, 50 min and 60 min after the end of the session.

All measurements were performed by the same evaluator, and previous test-retest scores in our laboratory resulted in an intraclass correlation coefficient of 0.991 and 0.997, coefficient of variation of 0.13 and 0.22, standard error of measurement of 1.13 mmHg and 1.11 mmHg, and minimal detectable change of 3.68 mmHg and 3.07 mmHg, for SBP and DBP, respectively.

Muscular strength

Maximal dynamic muscular strength was evaluated using the 1RM test assessed for chest press, knee extension, and preacher curl performed in the order listed. Testing 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 1RM. This warm-up was also used to familiarize the participants with the testing equipment and lifting technique. The testing procedure was initiated 2 min after the warm-up set. The participants were instructed to try to accomplish two repetitions with the load in three attempts in both exercises. The rest period was 3 to 5 min between each attempt, and 5 min between exercises. The 1RM was recorded as the last resistance lifted in which the subject was able to complete only one repetition[10]. Technique for each exercise was standardized and continuously monitored to ensure reliability. All 1RM testing sessions were supervised by two experienced researchers to maximize safety and test reliability. Verbal encouragement was given throughout each test. Three 1RM sessions were performed separated by 48 h (intraclass correlation coefficient ≥ 0.96). The highest load achieved among the 3 sessions was used for analysis in each exercise. Total muscular strength was determined as the sum of the three exercises.

Resistance training program

Supervised RT was performed in the State University fitness facility. The protocol was based on recommendations for RT in older population to improve muscular fitness[11,12] and also it was in accordance with the prescription recommended for hypertensive patients[13]. Physical education professionals personally supervised all training sessions to help ensure consistent and safe performance. Participants performed RT using a combination of free weights and machines. The sessions were performed three times per week on Mondays, Wednesdays, and Fridays during the morning hours, additionally, each RT session had a duration of approximately 45 min. The RT program was a whole body program with eight exercises comprising one exercise with free weights and seven with machines, performed in the following order: chest press, horizontal leg press, seated row, knee extension, preacher curl (free weights), leg curl, triceps pushdown, and seated calf raise.

Participants performed 3 sets of 8-12 repetitions maximum, and each set was executed until muscle failure or an inability to sustain exercise performance with proper form. Participants were instructed to inhale during the eccentric phase and exhale during the concentric phase while maintaining a constant velocity of movement at a ratio of approximately 1:2 seconds (concentric and eccentric phases, respectively). Participants were afforded a 1 to 2 min rest interval between sets and 2 to 3 min between each exercise. Instructors adjusted the loads of each exercise according to the subject's abilities and improvements in exercise capacity throughout the study in order ensure that the subjects were exercising with as much resistance as possible while maintaining proper exercise technique. Progression was planned so that when 12 repetitions within a given exercise were completed on two consecutive training sessions the weight was increased 2-5% for the upper limb exercises and 5-10% for the lower limb exercises[11].

Statistical analysis

Normality was checked by Shapiro-Wilk's test. Data were expressed as mean and standard deviation. A paired t-test was applied to compare pre- and post-training scores. Levene's test was used to analyze the homogeneity of variances, and analysis of variance (ANOVA) for repeated measures was used for comparison between BP measurements before and after acute exercise. When an F-ratio was significant, Scheffé post hoc test was employed to identify the mean differences. The Pearson correlation was used to verify the correlation between the acute and chronic changes in BP. Additionally, simple linear regression was used to investigate the association between the post-exercise moments that showed a p value < 0.20 with changes in BP after the RT program. For all statistical analyses, the significance was accepted at 5%. The data were analyzed using STATISTICA software version 10.0 (Statsoft Inc., Tulsa, OK, USA).

Results

Table 1 shows the participants characteristics at pre- and post-training. Of the 25 participants were hypertensive. Significant increase for total muscular strength (+11.8%) and a significant decrease for SBP (-5 mmHg) was observed after the intervention period. However, the DBP did not change after the RT intervention.

Table 1. General characteristics of the older women at pre- and post-training (n = 25)

Variables	**Pre-training**	**Post-training**
Age (years)	67 (5)	67 (5)
Body mass (kg)	65 (11)	65 (12)
Height (cm)	155 (5)	154 (6)
Body mass index (kg/m^2)	27 (4)	27 (5)
Resting SBP (mmHg)	121 (12)	115 (11)*
Resting DBP (mmHg)	69 (10)	68 (8)
Chest press 1RM (kg)	35 (4)	38 (5)*
Knee extension 1RM (kg)	38 (7)	44 (8)*
Preacher curl 1RM (kg)	19 (3)	22 (3)*
Total strength (kg)	93 (12)	104 (14)*

Note: Data are presented as mean and standard deviation. * P < 0.001 vs pre-training. SBP = systolic blood pressure. DBP = diastolic blood pressure.

Table 2 shows the acute and chronic changes in BP. The SBP decreased at all times after a single session of resistance exercise, while DBP increased after 40 min. Chronically, only SBP showed a significant decrease ($p < 0.001$). Nineteen participants (76% of the sample) decreased SBP more than the minimal detectable chronic change for SBP (3.68 mmHg). Twenty-four participants (96% of the sample) reached the PHE at 20 min post-exercise.

Table 2. Changes in blood pressure after acute and chronic resistance exercise in older women (n = 25).

	SBP (mmHg)	**DBP (mmHg)**
Acute		
10 min	-5 (6)*	1 (5)
20 min	-9 (5)*	1 (4)
30 min	-7 (6)*	1 (4)
40 min	-6 (6)*	2 (4)*
50 min	-5 (7)*	3 (5)*
60 min	-4 (8)*	3 (6)*
Chronic		
Resting value	-5 (3)**	- 1 (5)

Note: Data are presented as mean and standard deviation. * $P < 0.05$ vs. pre-exercise. ** $P < 0.001$ vs. pre-training. SBP = systolic blood pressure. DBP = diastolic blood pressure.

The reduction observed in SBP after a single RT session at baseline showed positive and significant correlations with the reductions in basal SBP observed after the 8 weeks of RT. The strongest correlations were observed at 20 min after the exercise session (Table 3).

Table 4 shows the linear regression between chronic and acute changes. A linear relationship between the changes in chronic SBP and acute SBP was observed. The linear regressions between the magnitude of change in chronic BP and the 20 min for SBP, and 30 min for DBP of post-exercise are shown in Figure 2.

Table 3. Pearson product moment correlation between the magnitude (Δ) of post-exercise hypotension and chronic changes on systolic and diastolic blood pressures in older women (n = 25).

	Systolic blood pressure		**Diastolic blood pressure**	
	R	***p***	**r**	***p***
Δ 10 min after acute exercise	0.48	0.01	0.18	0.40
Δ 20 min after acute exercise	0.77	0.04	-0.09	0.67
Δ 30 min after acute exercise	0.43	0.03	0.28	0.18
Δ 40 min after acute exercise	0.47	0.02	0.11	0.60
Δ 50 min after acute exercise	0.42	0.04	0.11	0.61
Δ 60 min after acute exercise	0.27	0.20	-0.09	0.65

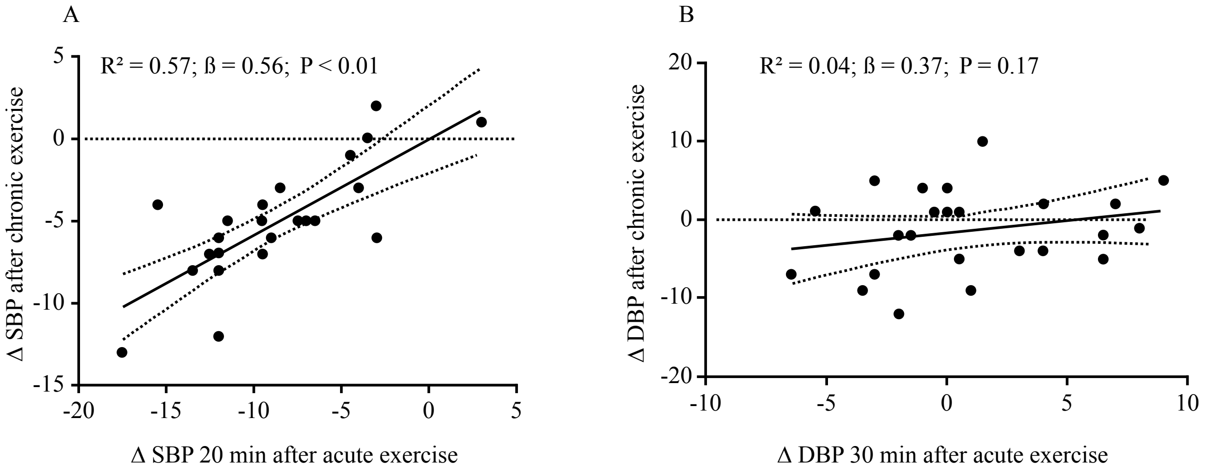
Table 4. Linear regression to predict chronic decrease of systolic blood pressure (SBP) and diastolic blood pressure (DBP) from the acute values after a resistance exercise session in older women (n = 25).

	R^2	**Beta**	**SE**	***p***	**CI95%**
Acute SBP					
Δ 10 min	0.19	0.31	0.12	0.02	0.06-0.56

Δ 20 min	0.57	0.56	0.09	< 0.01	0.36-0.76
Δ 30 min	0.15	0.27	0.12	0.03	0.03-0.52
Δ 40 min	0.19	0.26	0.10	0.02	0.05-0.47
Δ 50 min	0.14	0.21	0.10	0.04	0.01-0.41
Δ 60 min	0.03	0.14	0.10	0.19	-0.07-0.34
Acute DBP					
Δ 10 min	-0.12	0.18	0.22	0.41	-0.27-0.64
Δ 20 min	-0.04	-0.1	0.27	0.67	-0.68- 0.44
Δ 30 min	0.04	0.34	0.24	0.17	-0.17-0.84
Δ 40 min	-0.03	0.14	0.26	0.60	-0.39-0.66
Δ 50 min	-0.03	0.12	0.23	0.62	-0.36-0.59
Δ 60 min	-0.03	-0.08	-0.09	0.66	-0.45-0.29

Note: R^2 = coefficient of determination. SE = standard error. CI95% = confidence interval at 95%. SBP = systolic blood pressure. DBP = diastolic blood pressure.

Figure 2. Linear regression of systolic blood pressure (SBP) and diastolic blood pressure (DBP) between the magnitudes of change in chronic resistance exercise and the 20 min for SBP (A), 30 min for DBP (B) after acute resistance exercise in older women (n = 25).



Discussion

The main finding of the present study was that the PEH observed before a RT program intervention was associated with the chronic decrease in resting SBP in older women following 8 weeks of RT, and that this correlation was strongest at 20 min after the acute session. Previously, two studies[3,4] analyzing aerobic exercises in men and women aged 30-60 years old reported the correlation between acute and chronic decrease in SBP (r = 0.77)[4] or SBP (r = 0.89) and DBP (r = 0.75)[3]. Tibana et al.[7] investigated the correlation between acute and chronic decrease in BP following 8 weeks of RT in normotensive women aged from 18 to 49 years and observed strong correlation between acute and chronic response for both SBP (r = 0.81) and DBP (r = 0.69). Our results advance these findings adding to the body of knowledge showing reduction of BP following RT in older women.

Despite some previous studies have reported no chronic reduction on resting BP after a RT protocol[14-16], which could be related with the characteristics of the sample and/or with the duration or intensity of the program applied, the magnitude of the reduction found in the present study (- 5mmHg for SBP) is in accordance with the most recent meta-analysis in this topic[17].

The mechanisms underlying the acute and chronic reduction in BP due to RT are not completely understood and seem to be multifactorial. Queiroz et al.[18] suggest that PEH is associated with decreased cardiac output and/or lower peripheral vascular resistance, both of which could be caused by lowered sympathetic activity, reduced transduction for vascular tone[19,20], and/or greater release of nitric oxide[21]. Regarding the chronic reduction of resting BP, studies suggest that the exposure to moderate-to-high training loads in each acute RT session and, consequently, to higher peak BP achieved during exercise may be the stimulus for a baroreflex adaptation[15,22]. This could lead to a chronic reduction in sympathetic activity and, consequently, lowering peripheral vascular resistance[22]. Further, it is possible that acute responders may present higher nitric oxide release, which also could be related to training-induced chronic adaptations, but this should be confirmed by futures studies.

The important and novel finding of our study was the analysis of the strongest time-point correlation, in which PEH 20 min post-exercise showed the strongest correlation explaining 57% of the chronic BP lowering induced by RT. This means that for every 1 mmHg reduction in SBP after 20 min of the acute session represents a decrease of 0.56 mmHg in resting SBP after 8 weeks of RT in older women. Therefore, measurement of PEH at 20 min after exercise may be enough to predict the chronic response of BP associated with a RT program. The greater correlation observed at 20 min of PEH may be related to the greatest decrease, since at 20 min after the exercise the greatest lowering in SBP among the time points was observed.

Moreira, Cucato, Terra, Ritti-Dias[23] observed the changes SBP after acute RT session (60 min) were correlated with the chronic changes in resting SBP after RT intervention ($r = 0.47$; $P = 0<03$), and also observed for DBP ($r = 0.70$; $P = 0<01$) in medicated hypertensive elderly women. Tibana et al.[7] reported that the greatest value of BP decrease produced the strongest correlations with chronic BP reduction. The greatest reduction at approximately 20 min has also received support[24]. Therefore, our results corroborate literature, RT regular practice is important positive changes in BP and may have a protective effect on the cardiovascular system[7,24,25].

The RT protocol used in our experiment was based on the recommendations to older adults to improve muscular fitness[26]. This training was effective to elicit increases in muscular strength as observed in the 1RM. Moreover, the RT protocol was effective to lower the SBP. These results reinforce the importance of RT for older adults[26] and as a complement tool in prevention and non-pharmacological treatment of hypertension[27,28]. Moreover, the acute response of SBP after a single session of resistance exercise can predict the extent of BP lowering associated with chronic training interventions.

The increase in DBP observed 40 min after the acute session of RT could be explained by alterations in peripheral vascular resistance, which tends to remain elevated during the first hours after resistance exercise in older adults[29], a fact which is probably not compensated for by a decrease of cardiac output. This possibility, however, should be investigated in future studies.

The present study has some limitations. The lack of other cardiovascular variables that could influence the decrease on BP (i.e. cardiac output, peripheral resistance, arterial stiffness and cardiac autonomic modulation) might further explain the mechanisms underlying the acute and chronic responses of BP due to RT, and the relationship between both. Additionally, the absence of a control group should also be considered, for it could help in the interpretation of our results regarding the effectiveness of the RT program and the benefits for BP.

Conclusion

We conclude that the acute BP lowering after RT session is a reliable predictor of chronic BP response to exercise training in older women. Twenty minutes of resting, after RT training, is enough to indicate chronic response of BP as this measure was highly associated with chronic BP lowering in older women. From a clinical point of view, our results may be helpful to identify individuals who are responsive to this type of exercise prescription.

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**Corresponding author:*

Erick H. P. Eches
Physical Education - Universidade Estadual de Londrina - Cx. Postal 10.011 – Campus Universitário, Londrina/ PR, Brazil.
Email: erick_eches@hotmail.com

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