Motriz, Rio Claro, v. 28, n. Especial 2, 2022, e10220005122 *DOI: http://dx.doi.org/10.1590/s1980-657420220005122*
Special Issue: Physical Training in Older Adults

Acute and Chronic Effects of Exercise in Health

Effect of the execution order from concurrent exercise session on blood pressure responses in hypertensive older men

Denise Rodrigues Fernandes[1], Tássia Magnabosco Sisconeto[1], Sara Silva Freitas[1], Tállita Cristina Ferreira Souza[1], Rodrigo Sudatti Delevatti[2], Rodrigo Ferrari[3,4], Guilherme Morais Puga[1], Ana Carolina Kanitz[4]

[1]Universidade Federal de Uberlândia, Faculdade de Educação Física e Fisioterapia, Uberlândia, MG, Brazil; [2]Universidade Federal de Santa Catarina, Departamento de Educação Física, Florianópolis, SC, Brazil; [3]Universidade Federal do Rio Grande do Sul, Programa de Pós-Graduação em Cardiologia, Porto Alegre, RS, Brazil; [4]Universidade Federal do Rio Grande do Sul, Escola de Educação Física, Fisioterapia e Dança, Porto Alegre, RS, Brazil.

Associate Editor: Eduardo Lusa Cadore Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil. E-mail: edcadore@yahoo.com.br.

Abstract - Aim: To compare blood pressure (BP) responses among the different orders of execution of concurrent exercise (CE) sessions in controlled hypertensive older men. **Methods:** Fifteen older men (64 ± 5 years) participated in three randomized crossover sessions: control session (C), CE in aerobic-resistance order (AR), and resistance-aerobic order (RA). The CE was performed for 1 h, in which 30 min were for the resistance exercise with 5 exercises at 70% of 1RM and 30 min for the aerobic exercise on a treadmill with intensity corresponding to the first ventilatory threshold. Clinical systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean blood pressure (MBP) were measured at rest and over 2 h and 24 h after the session. For analysis, the Generalized Estimating Equations (GEE) test was used with Bonferroni's complimentary test ($\alpha = 0.05$). **Results:** The SBP decreased by 30 min after AR, while after RA we obtained reductions during 1 h after a session concerning rest. Between sessions, we found lower values in both CE compared to the C at 30 min, 45 min, and 90 min. In the RA there was a lower pressure in relation to the C at minute 60. The DBP reduced 30 min after the AR regarding the pre-session, however with no difference between sessions. The MBP was lower in relation to 30 min rest after AR. Among sessions, a pressure drop was observed in the AR compared to the C at 30 min and 45 min. **Conclusion:** We can conclude that the CE was effective in generating post-exercise hypotension regardless of the order in controlled hypertensive older men.

Keywords: combined exercise, hypertension, aging, post-exercise hypotension.

Introduction

Aging is a natural phenomenon and can cause several physiological changes in the human body, such as a drop in strength and muscle mass[1] reductions in aerobic fitness[2,] and increase arterial stiffness[3]. Consequently, older people may be affected by several chronic diseases, such as Arterial Hypertension. About 31% of the adult population worldwide was diagnosed with Arterial Hypertension in 2010 (1.4 billion)[4], which is considered an important public health problem in the world[5].

One of the non-pharmacological intervention methods to treat, prevent and control Arterial Hypertension is the regular practice of physical exercise[6]. Physical exercise can influence blood pressure (BP) behavior with a single session, reducing BP values below the values at rest or below the levels measured on a control day without the practice of exercise. This effect is known as Post-Exercise Hypotension (PEH)[7,8]. PEH has clinical relevance for lasting several hours and for having its response associated with chronic BP reduction[8,9]. A meta-analysis[10] observed reductions in systolic (SBP) and diastolic BP (DBP) after aerobic exercise, resistance exercise, and concurrent exercise. In addition, they demonstrated that the hypotensive effect can be inversely proportional to the volunteer's age due to increased arterial stiffness and vessel thickness, decreased compliance, and capillary density.

It is already known that both the aerobic session and the resistance session performed separately present the PEH effect but through different mechanisms[26]. There is also a consensus in the literature that aerobic exercise appears to have a more significant effect on PEH responses[10]. Concurrent exercise is widely indicated for the older population for providing improvements in strength, functionality, and cardiorespiratory capacity[11-16]. However, there are still few studies that assess the effects of a concurrent session on BP responses. Most existing studies are carried out with the young adult population[17-23] and few in the population with a higher prevalence of Arterial Hypertension, the older adults[24,25].

In the concurrent session, there is a hypothesis that the use of resistance exercises at the end of the session may attenuate the vasodilator effect of the aerobic exercise performed at the beginning, minimizing the PEH responses[20]. However, this is not well documented in the literature though.

In the literature, we found only two studies that evaluated the order of CE sessions in the BP responses, and these studies did not observe differences between the different exercise orders[18,21]. It is worth mentioning that these studies were carried out with normotensive adults, they did not present a control session and they monitored the BP only for 60 min. Thus, there is a gap in studies among the older hypertensive public, which presents a control session and that makes longer monitoring of BP after the exercise session. The present study aimed to compare BP responses among the different orders of execution of a concurrent exercise session (aerobic-resistance and resistance-aerobic) in hypertensive older men. This study hypothesizes that the concurrent session in the resistance-aerobic order will be able to decrease the BP values to levels below those at rest with greater magnitude than the inverse order.

Methods

The present study is characterized as a randomized crossover clinical trial involving physical exercises for controlled hypertensive older men. This clinical trial was designed following the recommendations of the Consolidated Standards of Reporting Trials (CONSORT)[27].

Participants

Volunteers were recruited throughout the study through dissemination on social media and posters in different parts of the city in the period between July/2018 and June/2019. The sample was selected at random, voluntarily. To participate in the study, the volunteers should be men aged 60 to 80 years old with a previous diagnosis of controlled hypertension, not having participated in physical exercise programs regularly in the last three months before the beginning of the study. They could not have complications that prevented physical exercise participation, do not be smokers, do not have a pacemaker, have no previous diagnosis of Diabetes Mellitus, and do not have obesity equal to or greater than stage 2 (BMI $\geq$ 35 kg. m^{-2}). Volunteers who met the inclusion criteria signed a Free and Informed Consent Term (FICT) and were allocated in a pre-elaborated table for randomization. Protocol registered with the Brazilian Registry of Clinical Trials - ReBEC (RBR-4d4q42). The project by the Ethics and Research Committee of the Federal University of Uberlândia (CAAE: 89086118.2.0000.5152).

Experimental design and procedures

After reading and signing the FICT, the sample characterization variables were measured. The body mass, fat mass, and lean mass were determined from a polar tetra bioimpedance exam (InBody 230 Trepel®, Perafita, Portugal). Height was measured using a fixed stadiometer (Sanny®, São Bernardo do Campo, SP, Brazil) and the waist circumference was determined with a 0.1 mm scale using measuring tape (Filizola®, São Paulo, SP, Brazil). The International Physical Activity Questionnaire (IPAQ short version) was applied to identify the participants' level of physical activity[28]. Subsequently, two familiarization sessions were held with the equipment and procedures for performing aerobic and resistance exercises.

After, there were test sessions to assess the intensity of aerobic exercise using an incremental test on a treadmill (Movement® E740, Pompeia, São Paulo, Brazil) and the intensity of resistance exercises through the test of a maximum repetition (1RM) and its reproducibility. Then, the participants performed three experimental sessions in a randomized block order: a concurrent exercise session in the order of aerobic-resistance (AR); a concurrent exercise session in the order of resistance-aerobic (RA); and a control session without exercise (C) with the same time, place and time established for the other sessions. A 48-h *wash-out* period was implemented during the sessions.

Cardiopulmonary test

The intensity of the aerobic exercise was determined based on an incremental test of inclination and speed on a treadmill following the modified Bruce progressive test protocol[29]. From it, the inclination and the speed corresponding to the first ventilatory threshold (VT1) used to control the intensity of aerobic exercise were determined. A gas analyzer (Quark PFT Ergo®, Cosmed, Rome, Italy) was used and the point corresponding to VT1 was determined by two experienced physiologists. In cases of disagreement, a third physiologist was consulted. The evaluation was considered valid when an effort perception of 8 (Borg scale 0-10) was reached or when the volunteer asked to stop the test.

One repetition maximum test (1RM)

The intensity of the resistance exercises was determined according to the 1RM test to obtain the maximum dynamic strength (in kg). The value of 1RM was considered as the maximum possible load to exercise in the concentric phase of the exercises: bench press, lat pulldown, shoulder press, squat, and 45° leg press. They were performed in two days with a minimum interval of 48 h, in which the second one was to check the reproducibility of the first test. No pause was allowed between the eccentric and concentric phases between repetitions. A warm-up of 10 repetitions with a minimum load was performed. The maximum load for everyone was determined with no more than 5 attempts and with a 5-min recovery period between attempts. If the 1RM load was not determined, the test would continue on another date with a minimum interval of 24 h. From the number of maximum repetitions achieved at each attempt, the load was resized aiming at the load corresponding to 1RM through the values proposed by the Lombardi coefficient[30].

Experimental protocol

The volunteers participated in three sessions, one for control and two for exercise. All experimental sessions lasted 1 h (8:00-9:00 am). At the beginning of each session, the participants were in a sitting position with the left arm resting on a surface at heart level for 10 min to measure the BP at rest in triplicate and afterward start the session. BP was measured using the oscillometric method, with an automatic calibrated and validated device[31] (Omron® HEM 7113, Shimogyo-Ku, Kyoto, Japan). The aerobic exercise was performed on a treadmill for 30 min at the speed and inclination corresponding to the stage where VT1 was found. Resistance exercises were performed with an intensity equivalent to 70% of 1RM in 3 sets of 8 to 12 repetitions with 60 seconds of rest between sets and exercises. The control session was carried out for the same duration as the other sessions and in the same environment. Afterward, the subjects were instructed to sit in the same place where the initial BP was measured for the measurements over 2 h every 15 min.

The average room temperature and relative humidities were 24.5 ± 2 °C and 61.5 ± 8.8%, respectively. After this procedure, the older men were asked to maintain their daily activities normally and return to the laboratory 24 h after the session for the final measurement. The volunteer was asked to avoid caffeine and exercise 24 h before and after the session. Three measurements were made, and the average of these values was considered for analysis. To calculate the MBP, the SBP and DBP measurements were used for the formula: MBP = DBP + (SBP-DBP) / 3.

Statistical analyses

Descriptive statistics were used, with values presented as mean and standard deviation. The sample "n" was calculated based on a study that used a similar design[19]. The calculation was performed in the G*Power 3.1[32] considering α value of 0.05, power analysis of 80%, correlation among rep measures of 0.5, nonsphericity correction ε in 1, and an effect size f of 0.22. Thus, we found the need for a minimum total "n" of 8 volunteers per session.

Statistical comparisons were performed using the Generalized Estimating Equations (GEE) method with Bonferroni´s post hoc test. Moreover, the area under the curve (AUC) was calculated using the trapezoidal method using the GP Prism 5.0. The Shapiro-Wilk test was used for normality and ANOVA for repeated measures for comparison among sessions. For all evaluations, the significance level adopted was $\alpha = 0.05$ and all statistical tests were performed using SPSS 20.0.

Results

Figure 1 shows the flowchart with the distribution of the study participants.

The main characteristics of the volunteers are shown in Table 1.

Regarding the BP values measured during the exercise sessions, ie, intra-session, we observed a more marked increase in mean SBP after resistance exercise in an AR session (A: 132 ± 18 mmHg; R: 138 ± 26 mmHg). In the RA session, we observed a more marked increase in resistance exercise in an RA session (R: 145 ± 28 mmHg; A: 122 ± 20 mmHg). About mean DBP, we observed a more marked increase after aerobic exercise in the AR session (A: 80 ± 12 mmHg; R: 76 ± 16 mmHg). In the RA session, we observed a greater increase after resistance exercise (R: 86 ± 15 mmHg; A: 78 ± 15 mmHg).

In Figure 2 we present the mean ± standard deviation of the SBP, MBP and DBP values at rest and after the experimental sessions. In SBP, there were significant differences in time ($p < 0.001$) and interaction ($p < 0.001$). A pressure drop was observed in the AR session in relation to rest only 30 min after the session (REP: 118 ± 12 mmHg; 30': 110 ± 13 mmHg; $p = 0.004$). In the RA session, SBP decreased at 15' (111 ± 12 mmHg; $p = 0.022$), 30' (110 ± 14 mmHg; $p = 0.025$), 45' (111 ± 11 mmHg; $p < 0.001$) and 60' (111 ± 14 mmHg; $p = 0.017$) regarding the rest (REP: 118 ± 12 mmHg). There was no pressure decline in the C session. Among the sessions, significantly lower values were observed in exercise sessions compared to the control session at moments 30' (AR: 110 ± 13 mmHg; RA: 110 ± 14 mmHg; C: 121 ± 11 mmHg), 45' (AR: 112 ± 12 mmHg; RA: 111 ± 11 mmHg; C: 123 ± 11 mmHg) and 90' (AR: 113 ± 13 mmHg; RA: 114 ± 11 mmHg; C: 124 ± 11 mmHg). A pressure drop was observed in the RA session in relation to the control session 60 min after the session (RA: 111 ± 14 mmHg; C: 122 ± 11 mmHg; $p = 0.047$). In the AUC results of ΔSBP we found significant differences between the AR (−441 ± 976 mmHg.24 h) and RA (−614 ± 730 mmHg.24 h) sessions in relation to the C session (461 ± 847 mmHg.24 h; $p = 0.049$ and $p = 0.003$, respectively) without statistical differences among exercise sessions ($p > 0.999$).

In MBP, we did not find significant differences among sessions ($p = 0.154$), but in time ($p < 0.001$) and interaction ($p < 0.001$). In the AR session, there was a

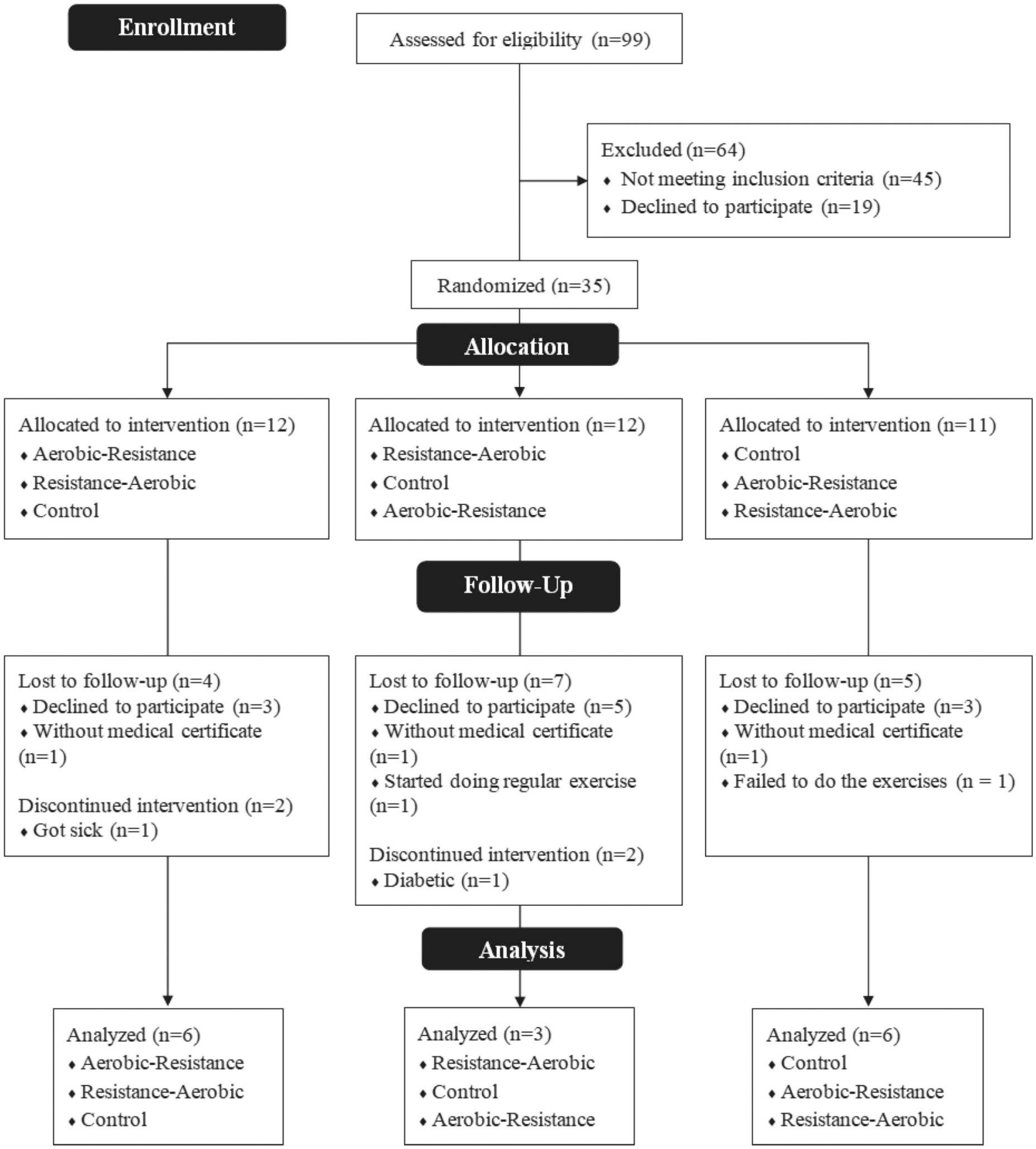

Figure 1 - Study flow diagram.

pressure drop in relation to rest in the 30th minute after exercise (REP: 87 ± 10 mmHg; 30': 81 ± 10 mmHg; $p = 0.005$) with subsequent normalization. In the RA session, we found no difference in the post-exercise moments regarding rest. In the C session, there was an increase in MBP 90 min compared to the rest (REP: 87 ± 9 mmHg; 90': 93 ± 10 mmHg; $p = 0.042$). Among sessions, a statistical difference was found between the 30 min (AR: 81 ± 10 mmHg; C: 90 ± 11 mmHg; $p = 0.034$) and 45 min (AR: 82 ± 10 mmHg; C: 91 ± 10 mmHg; $p = 0.039$). In the AUC data for ΔMBP, we found significant differences between the AR (−320 ± 661 mmHg.24 h) and RA (−406 ± 705 mmHg.24 h) sessions compared to the C session (431 ± 593 mmHg.24 h; $p = 0.016$ and $p = 0.004$, respectively) with no statistical differences among exercise sessions ($p > 0.999$).

In DPB, we found no statistical differences among the sessions ($p = 0.267$), only in time ($p < 0.001$) and interaction ($p < 0.001$). There was a pressure drop in the 30th minute after the AR session (REP: 72 ± 10; 30': 67 ±

Table 1 - General characteristics of the participants.

Variables	**n = 15**
Anthropometry	Mean ± SD
Age (years)	64 ± 5
Body mass (kg)	79.2 ± 11.5
Height (m)	1.70 ± 0.05
Body mass index (kg.m^{-2})	27.3 ± 3.9
Waist circumference (cm)	99 ± 13
Fat mass (%)	27.9 ± 7
Lean mass (%)	37.4 ± 11
Physical activity level	n (%)
Very active	1 (7)
Active	9 (60)
Irregularly active	4 (26)
Sedentary	1 (7)
Type of antihypertensive therapy	n (%)
None	1 (7)
One	5 (33)
Two or more	9 (60)
Maximum strength	Mean ± SD
1RM bench press (kg)	53 ± 13
1RM lat pulldown (kg)	54 ± 10
1RM shoulder press (kg)	49 ± 15
1RM squat (kg)	78 ± 21
1RM leg press (kg)	265 ± 79

SBP: systolic blood pressure; MBP: mean blood pressure; DBP: diastolic blood pressure; 1RM: one repetition maximum.

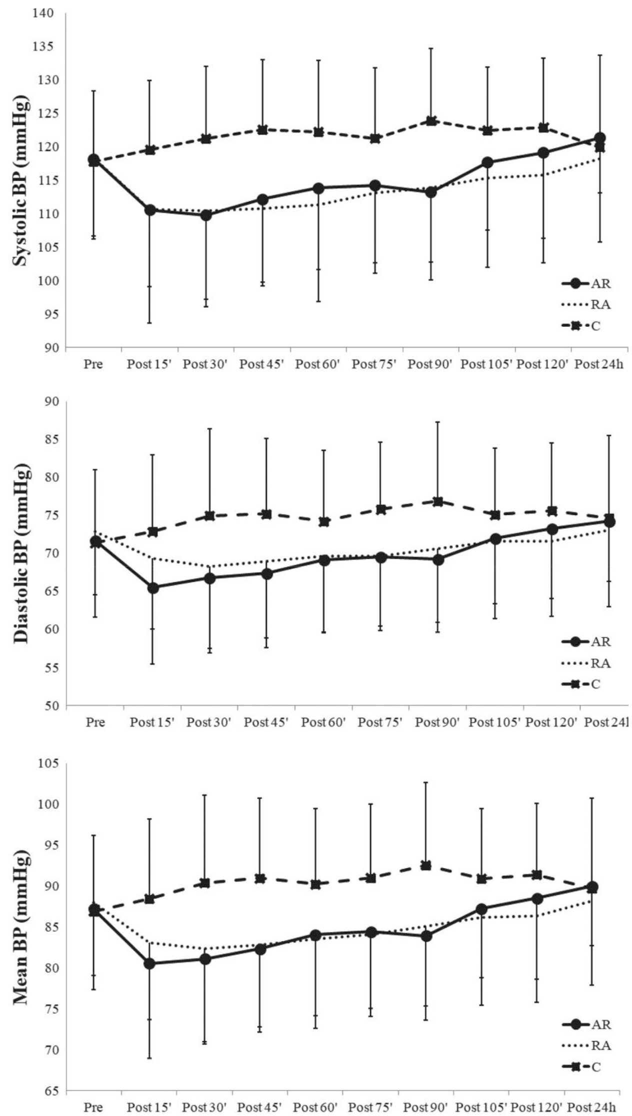

Figure 2 - Behavior of Systolic, Mean, and Diastolic Blood Pressure (BP) after a concurrent exercise session in aerobic-resistance (AR), resistance-aerobic (RA), and control (C) order. * difference in the AR session in relation to pre-exercise, # difference in the RA session in relation to pre-exercise, § difference in the C session in relation to pre-exercise, & difference in the C session in relation to the other sessions, $ difference between the RA session and the C session, α difference between the AR session and the C session.

10 mmHg; p = 0.041) followed by normalization of DPB. In the RA session, we found no significant difference without regard to rest. Finally, in the C session there was an increase in DPB at moments 75 (REP: 71 ± 10; 75': 76 ± 9 mmHg; p = 0.043) and 90' (77 ± 10 mmHg; p = 0.024). No statistical difference was found among sessions. In the AUC data of ΔDBP we found significant differences between the AR (−268 ± 577 mmHg.24 h) and RA (−304 ± 760 mmHg.24 h) sessions in relation to the C session (411 ± 544 mmHg.24 h; p = 0.009 and p = 0.010, respectively) without statistical differences among exercise sessions (p > 0.999).

Table 2 shows the SBP and DBP values in relation to the other sessions: a comparison of the AR and control (AR-C) sessions, RA, and control (RA-C) sessions, and the AR and RA (AR-RA) exercise sessions. We found that at no time were the two exercise sessions statistically different.

Discussion

Our findings suggest that both sessions can promote similar reductions in SBP, DBP, and MBP regardless of order. To our knowledge, this is the first study assessing whether there is an influence of concurrent exercise order in the BP reduction post-exercise in older hypertensive adults. These findings are of great importance for health professionals as they contribute to the prescription of exercises for the older people and hypertensive population since training is needed to improve muscle strength, and cardiorespiratory capacity as well as to control Arterial Hypertension.

We found in the scientific literature few studies that sought to analyze the effects of concurrent exercise on PEH. Even with great importance for the older men popu-

Table 2 - Differences in SBP and DBP between exercise sessions in relation to the control session (AR-C and RA-C) and between exercise sessions (AR-RA).

Variable	AR-C		RA-C		AR-RA	
	Mean ± SE (95% CI)	**p value**	**Mean ± SE (95% CI)**	**p-value**	**Mean ± SE (95% CI)**	**p value**
SBP (mmHg)						
Baseline	0.4 ± 3.9 (−8.9; 9.7)	< 0.999	0.6 ± 4.0 (−9.0; 10.2)	< 0.999	−0.2 ± 4.2 (−10.2; 9.8)	< 0.999
Post 30’	−11.4 ± 4.1 (−21.2; −1.5)	0.018*	−10.8 ± 4.7 (−21.5; −0.1)	0.048*	−0.6 ± 4.7 (−12.0; 10.7)	< 0.999
Post 60’	−8.3 ± 4.0 (−18.0; 1.4)	0.119	−10.9 ± 4.5 (−21.6; −0.1)	0.047*	2.5 ± 4.7 (−8.8; 13.8)	< 0.999
Post 90’	−10.6 ± 4.2 (−20.7; −0.4)	0.038*	−10.0 ± 3.9 (−19.3; −0.7)	0.030*	−0.6 ± 4.3 (−11.0; 9.7)	< 0.999
Post 120’	−3.7 ± 4.1 (−13.6; 6.15)	< 0.999	−7.1 ± 4.2 (−17.1; 2.9)	0.273	3.3 ± 4.6 (−7.6; 14.3)	< 0.999
Post 24 h	1.5 ± 4.0 (−8.1; 11.1)	< 0.999	−1.7 ± 4.6 (−12.8; 9.5)	< 0.999	3.1 ± 3.7 (−5.8; 12.1)	< 0.999
DBP (mmHg)						
Baseline	0.3 ± 3.5 (−8.0; 8.6)	< 0.999	1.4 ± 3.1 (−6.1; 8.9)	< 0.999	−1.1 ± 3.3 (−8.9; 6.7)	< 0.999
Post 30’	−8.2 ± 3.7 (−17.2; 0.8)	0.087	−6.6 ± 3.9 (−16.0; 2.7)	0.267	−1.5 ± 3.6 (−10.1; 7.2)	< 0.999
Post 60’	−5.1 ± 3.3 (−13.0; 2.9)	0.383	−4.6 ± 3.4 (−12.8; 3.6)	0.536	−0.5 ± 3.5 (−8.8; 7.8)	< 0.999
Post 90’	−7.6 ± 3.5 (−16.1; 0.9)	0.095	−6.2 ± 3.6 (−14.7; 2.3)	0.246	−1.4 ± 3.4 (−9.6; 6.8)	< 0.999
Post 120’	−2.4 ± 3.2 (−10.0; 5.2)	< 0.999	−4.0 ± 3.3 (−12.0; 4.0)	0.688	1.6 ± 3.4 (−6.5; 9.7)	< 0.999
Post 24 h	−0.4 ± 3.4 (−8.4; 7.6)	< 0.999	−1.5 ± 3.7 (−10.4; 7.3)	< 0.999	1.1 ± 3.2 (−6.5; 8.8)	< 0.999

Values: mean ± standard error (95% confidence interval); SBP: systolic blood pressure; MBP: mean blood pressure; DBP: diastolic blood pressure; AR: aerobic-resistance; RA: resistance-aerobic; C: control.

lation, there is a greater number of studies that sought to assess the PEH of concurrent exercises performed in a population of young adults[17-23] compared to the few articles upon the older[24,25]. Regarding the order of the sessions, we found only two studies with similar purpose[18,21], but both were carried out in normotensive youngsters. One study found pressure reductions in SBP, DBP, and MBP after AR session and minimal changes after exercise in the RA order[21], and the other study found similarity in pressure responses regardless of order[18].

In older women, Anunciação et al.[24] sought to analyze the effects of concurrent exercise (AR order) on post-exercise pressure responses and found significant reductions in SBP (30 and 60 min) and in DPB (10, 30, and 60 min) in relation to rest. This study partially agrees with our results since we found a decrease in SBP, however, DPB only changed 30 min after exercise in the AR session. The study by Ferrari et al.[25] also evaluated the effect of concurrent exercise (SE order) in hypertensive older adults and found significant reductions in DPB (10 to 40 min) and only a tendency to PEH in SBP. The authors’ justification is that possibly aging and/or Arterial Hypertension has reduced vascular compliance, thus affecting responses to stimuli caused by exercise.

Regardless of the results found in relation to the pre-exercise values, it is of great importance to highlight that both concurrent exercise sessions resulted in PEH without significant differences between them. These results contradict the study hypothesis and suggest that resistance exercise does not influence the vasodilator effect caused by aerobic exercise and that the two sessions possibly provide similar post-exercise cardiovascular responses. It is known that PEH can be caused by both a decrease in peripheral vascular resistance and a decrease in cardiac output. In the study by Rezk et al.[33] in normotensive youngsters, it was observed that resistance exercise reduced the cardiac output and that it was not completely compensated by peripheral vascular resistance. In the study by Rueckert et al.[38] performed with aerobic exercise in young hypertensive individuals, a pressure drop was observed, determined by the decrease in peripheral vascular resistance followed by the reduction in cardiac output. In older adults, the mechanisms may be different compared to those of young people. In studies carried out with older men, the effects of exercise on peripheral vascular resistance can be minimized due to the loss in arterial compliance caused by aging, thus reducing its vasodilator capacity[10]. Therefore, the mechanisms involved in the hypotensive effect caused by exercise in older men are due more to the reduction in cardiac output not compensated by peripheral vascular resistance.

Some possible limitations should be pointed out in this article. Post-exercise BP was assessed for a short period, so our results cannot be extrapolated to more lasting situations and we did not assess the hemodynamic mechanisms behind BP's responses. However, to minimize this limitation, we present the result of BP 24 h after exercise. Additionally, we think that we found interesting results even without the use of ambulatorial blood pressure monitoring - ABPM. Other limitations of our study: lack of ABPM use, and also a study carried out only with men. Nonetheless, we emphasize some strong points of our study, such as we conducted a control session to identify the behavior of BP on a non-exercise day, all sessions were held during the same period of the day, and previously trained and standardized evaluators participated in the study, and participation only hypertensive older men.

In summary, we can conclude that both orders of execution of a concurrent exercise session (aerobic-resistance and resistance-aerobic) with aerobic exercise on a treadmill with intensity corresponding to the first ventilatory threshold and resistance exercise at 70% of 1RM can provide PEH of similar magnitude and duration in controlled hypertensive older men. Our findings may have important practical applications as they provide an adequate prescription for physical exercise.

Conflict of interest statement

Declarations of interest: none.

Funding

Minas Gerais Research Funding Foundation (FAPEMIG), Coordination for the Improvement of Higher Education Personnel (CAPES), and Brazilian Council for Scientific and Technological (CNPq) Brazilian Government Association.

References

1. Frontera WR, Hughes VA, Lutz KJ, Evans WJ. A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. J Appl Physiol. 1985;71(2):644-50. doi
2. Astrand I, Astrand PO, Hallback I, Kilbom A Reduction in maximal oxygen uptake with age. J Appl Physiol. 1973;35 (5):649-54. doi
3. Alvim RO, Santos PCJL, Bortolotto LA, Mill JG, Pereira AC. Arterial stiffness: pathophysiological and genetic aspects. Int J Cardiovasc Sci. 2017;30(5):433-41. doi.
4. Mills KT, Bundy JD, Kelly TN, Reed JE, Kearney PM, Reynolds K, et al. Global disparities of hypertension prevalence and control: a systematic analysis of population-based studies from 90 countries. Circulation. 2016;134 (6):441-50. doi
5. Malachias MVB, Plavnik FL, Machado CA, Malta D, Scala LCN, Fuchs S. 7th Brazilian guideline of arterial hypertension: chapter 1 - concept, epidemiology, and primary prevention. Arq Bras Cardiol. 2016;107(3):1-6. doi
6. Herrod PJJ, Doleman B, Blackwell JEM, O'Boyle F, Williams JP, Lund JN, et al. Exercise and other nonpharmacological strategies to reduce blood pressure in older adults: a systematic review and meta-analysis. J Am Soc Hypertens. 2018;12(4):248-67. doi
7. Fitzgerald W. Labile hypertension and jogging: new diagnostic tool or spurious discovery? Br Med J. 1981;282 (6263):542-4. doi
8. Kenney MJ, Seals DR. Postexercise hypotension. Key features, mechanisms, and clinical significance. Hypertension. 1993;22(5):653-64. doi
9. Halliwill JR, Buck TM, Lacewell AN, Romero SA. Post-exercise hypotension and sustained post-exercise vasodilatation: what happens after we exercise? Exp Physiol. 2013;98(1):7-18. doi
10. Carpio-Rivera E, Moncada-Jiménez J, Salazar-Rojas W, Solera-Herrera A. Acute effects of exercise on blood pressure: a meta-analytic investigation. Arq Bras Cardiol. 2016;106(5):422-33. doi
11. Cadore EL, Pinto RS, Lhullier FLR, Correa CS, Alberton CL, Pinto SS, et al. Physiological effects of concurrent training in elderly men. Int J Sports Med.2010;31(10):689-97. doi
12. Cadore EL, Pinto RS, Bottaro M, Izquierdo M. Strength, and endurance training prescription in healthy and frail elderly. Aging Dis. 2014;5(3):183-95. doi
13. Cadore EL, Pinto RS, Teodoro JL, da Silva LXN, Menger E, Alberton CL, et al. Cardiorespiraroty adaptations in elderly men following different concurrent training regimes. J Nutr Health Aging. 2017;22(4):483-90. doi
14. Colleluori G, Aguirre L, Phadnis U, Fowler K, Armamento-Villareal R, Sun Z, et al. Aerobic plus resistance exercise in obese older adults improves muscle protein synthesis and preserves myocellular quality despite weight loss. Cell Metabolism. 2019;30(2):261-73. doi
15. Hurst C, Weston KL, McLaren SJ, Weston M. The effects of same-session combined exercise training on cardiorespiratory and functional fitness in older adults: a systematic review and meta-analysis. Aging Clin Exp Res. 2019;31 (12):1701-17. doi
16. Murlasits Z, Kneffel Z, Thalib L. The physiological effects of concurrent strength and endurance training sequence: a systematic review and meta-analysis. J Sports Sci. 2018;36 (11):1212-19. doi
17. Azevêdo LM, de Souza AC, Santos LES, dos Santos RM, de Fernandes MOM, Almeida JA, et al. Fractionated concurrent exercise throughout the day does not promote acute blood pressure benefits in hypertensive middle-aged women. Front Cardiovasc Med. 2017;4:6. doi
18. Domingues WJR, Soares AHG, Cavalcante BR, da Silva RRM, Nunhes PM, da Silva GMG, et al. Influence of the order of aerobic and resistance exercise on hemodynamic responses and arterial stiffness in young normotensive individuals. J Bodyw Mov Ther. 2019;24(2):79-84. doi
19. Keese F, Farinatti P, Pescatello L, Monteiro W. A comparison of the immediate effects of resistance, aerobic, and concurrent exercise on postexercise hypotension. J Strength Cond Res. 2011;25(5):1429-36. doi
20. Keese F, Farinatti P, Pescatello L, Cunha FA, Monteiro WD. Aerobic exercise intensity influences hypotension following concurrent exercise sessions. Int J Sports Med. 2012;33 (2):148-53. doi
21. Lovato NS, Anunciação PG, Polito MD. Blood pressure and heart rate variability after aerobic and weight exercises performed in the same session. Rev Bras Med Esporte. 2012;18(1):22-5. doi
22. Ruiz RJ, Simão R, Saccomani MG, Casonato J, Alexander JL, Reia M, et al. Isolated and combined effects of aerobic and strength exercise on post-exercise blood pressure and cardiac vagal reactivation in normotensive men. J Strength Cond Res. 2011;25(3):640-5. doi

23. Teixeira L, Ritti-Dias RM, Tinucci T, Mion Júnior D, Forjaz CLM. Post-concurrent exercise hemodynamics and cardiac autonomic modulation. Eur J Appl Physiol. 2011;111 (9):2069-78. doi
24. Anunciação PG, Farinatti PT, Goessler KF, Casonatto J, Polito MD. Blood pressure and autonomic responses following isolated and combined aerobic and resistance exercise in hypertensive older women. Clin Exp Hypertens. 2016;38(8):710-14. doi
25. Ferrari R, Umpierre D, Vogel G, Vieira PJC, Santos LP, de Mello RB, et al. Effects of concurrent and aerobic exercises on postexercise hypotension in elderly hypertensive men. Exp Gerontol. 2017;98:1-7. doi
26. Fecchio RY, de Brito LC, Peçanha T, Forjaz CLM. Exercício físico na redução da pressão arterial: por quê? Como? Quanto? Rev Hipertensão. 2017;20(1):3-15.
27. Dwan K, Li T, Altman DG, Elbourne D. CONSORT 2010 statement: extension to randomised crossover trials. BMJ. 2019;366:l4378. doi
28. Matsudo S, Araújo T, Matsudo V, Andrade D, Andrade E, Oliveira LC, et al. International physical activity questionnaire (IPAQ): a study of validity and reliability in Brazil. Rev Bras Ciênc Esporte. 2001;6:5-18. doi
29. Meneguelo RS, Araújo CFS, Stein R, Mastrocolla LE, Albuquerque PF, Serra SM. III Diretrizes da Sociedade Brasileira de Cardiologia sobre teste ergométrico. Arq Bras Cardiol. 2010;95(5):1-26. doi
30. Lombardi VP. Beginning weight training: the safe and effective way. Dubuque, Brown & Benchmark Pub; 1989.
31. Asmar R, Khabouth J, Topouchian J, Feghali R, Mattar J. Validation of three automatic devices for self-measurement of blood pressure according to the International Protocol: the Omron M3 intellisense (HEM-7051-E), the Omron M2 compact (HEM 7102-E), and the Omron R3-I plus (HEM 6022-E). Blood Press Monit. 2010;15(1):49-54. https://doi.org/10.1097/MBP.0b013e3283354b11
32. Faul F, Erdfelder E, Lang A-G, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007;39:175-91. doi
33. Rezk CC, Marrache RC, Tinucci T, Mion Júnior D, Forjaz CLM. Post-resistance exercise hypotension, hemodynamics, and heart rate variability: influence of exercise intensity. Eur J Appl Physiol. 2006;98(1):105-12. doi
34. Brito AF, de Oliveira CVC, Brasileiro-Santos MS, Santos AC. Resistance exercise with different volumes: blood pressure response and forearm blood flow in the hypertensive elderly. Clin Interv Aging. 2014;12:2151-8. doi
35. Cavalcante PAM, Rica RL, Evangelista AL, Serra AJ, Figueira Júnior A, Pontes Júnior FL, et al. Effects of exercise intensity on postexercise hypotension after a resistance training session in overweight hypertensive patients. Clin Interv Aging. 2015;10:1487-95. doi
36. Binder RK, Wonisch M, Corra U, Cohen-Solal A, Vanhees L, Saner H, et al. Methodological approach to the first and second lactate threshold in incremental cardiopulmonary exercise testing. Eur J Cardiovasc Prev Rehabil. 2008;15 (6):726-34. doi
37. Cadore EL, Izquierdo M, Pinto SS, Alberton CL, Pinto RS, Baroni BM, et al. Neuromuscular adaptations to concurrent training in the elderly: effects of intrasession exercise sequence. Age Dordrecht. 2013;35(3):891-903. doi
38. Rueckert PA, Slane PR, Lillis DL, Hanson P. Hemodynamic patterns and duration of post-dynamic exercise hypotension in hypertensive humans. Med Sci Sports Exerc. 1996;28 (1):24-32. doi

Corresponding author

Denise Rodrigues Fernandes. Universidade Federal de Uberlândia, Faculdade de Educação Física e Fisioterapia, Uberlândia, MG, Brazil.
E-mail: denise.r.fernandes@hotmail.com.

Manuscript received on March 21, 2022
Manuscript accepted on June 25, 2022