Effects of Exercise Order of Combined Power and Endurance Training on Arterial Stiffness and Hemodynamic Parameters in Previously Trained Hypertensive Older Adults

Bruno Bavaresco Gambassi, PhD[1,2,3,4,5,6], Beatriz de Sá Mota, B.SC.[1], David Guilherme Marques, B.SC.[1], Daniel Yakovi Ribeiro, B.SC.[1], Vinícius Silva, B.SC.[1], Luiz Alexandre Nunes, MSC[2], Fabiano de Jesus Furtado Almeida, PhD[2], Mayara Aragão, MSC[6,7], Celsiane do Espírito Santo Costa, M.SC. STUDENT[1,4], Roberto Bianco, PhD[2], María Rúa-Alonso, PhD[8], Paulo Adriano Schwingel, PhD[1,6,7]

[1]Laboratory of Education and Research in Exercise and Cardiovascular Health in Older Adults, Ceuma University, São Luís, Brazil; [2]Ceuma University, São Luís, Brazil; [3]Postgraduate Program in Management and Health Care, Ceuma University, São Luís. Brazil; [4]Postgraduate Program in Physical Education, Federal University of Maranhão, São Luís, Brazil; [5]Interuniversity Network for Healthy Aging, Latin America and the Caribbean, Talca Universidad, Chile; [6]Human Performance Research Laboratory, University of Pernambuco, Petrolina, Brazil; [7]Postgraduate Program in Rehabilitation and Functional Performance (PPGRDF), University of Pernambuco, Petrolina, Brazil; [8]Performance and Health Group, Faculty of Sports Sciences and Physical Education, Department of Physical Education and Sports, University of A Coruna, A Coruña, Spain

https://doi.org/10.5770/cgj.29.895

ABSTRACT

Background

Combining power training (PT) with endurance training (ET) offers health benefits for older adults. However, little is known about the effects of PT plus ET on arterial stiffness and hemodynamic parameters in previously trained hypertensive older adults. Additionally, the effects of exercise order—PT followed by ET versus ET followed by PT—on arterial stiffness and hemodynamic parameters remain unclear in older adults.

Objective

This study aimed to a) examine the effects of concurrent training (CT) on arterial stiffness and hemodynamic parameters in previously trained hypertensive older adults; and b) to investigate the effects of concurrent PT and ET exercise order on arterial stiffness and hemodynamic parameters in previously trained hypertensive adults.

Methods

Older adults with grade 1 hypertension were randomized into two groups: PT then ET group (DPTETG) and ET then PT group (ETDPTG). Both groups trained twice weekly for 16 weeks. Arterial stiffness and hemodynamic parameters were measured at baseline and after 16 weeks.

Results

No significant changes in arterial stiffness or hemodynamic parameters emerged after 16 weeks in either group ($p > .05$).

Conclusion

This study demonstrates that 16 weeks of different exercise orders of concurrent power and ET do not change arterial stiffness and hemodynamic parameters in older adults with hypertension.

Key words: older adults, hypertension, arterial stiffness, intervention

INTRODUCTION

Studies have demonstrated various benefits of traditional resistance training (RT) and endurance training (ET) on health parameters in older adults. Traditional RT has improved bone mineral density, and functional and cardiovascular parameters in older adults.(1-4) Moreover, aerobic training improves cardiovascular and metabolic parameters.(5-7)

In this sense, combining traditional RT with ET in training programs is recommended to achieve several health benefits for older adults.(8,9) Additionally, according to Izquierdo *et al*.,[9] combining traditional RT with ET sequentially in the same session is called concurrent training. On the other hand, performing traditional RT and ET on separate days is called combined training.[9]

In addition to practicing traditional RT with ET, Izquierdo *et al*.[8] also recommend power training (PT) for optimal aging and maintenance of functional capacities. Combining traditional RT or PT with ET is the most effective method for enhancing neuromuscular and cardiorespiratory functions in older adults.[9]

Although studies have observed the benefits of associating PT with ET for older adults' health,[10-13] little is known about the effect of these combinations on arterial stiffness in hypertensives, for which concurrent training involving PT seems promising.[12] Arterial stiffness decreased, and hemodynamic parameters improved after hypertensive older adults practiced only eight weeks of concurrent training involving PT and ET.[12] In the same line, pulse pressure and systolic blood pressure improved in older adults after PT associated with ET in the same session.[13]

Despite the benefits of combining traditional RT or PT with ET to older people's arterial stiffness,[14,15,12] there is no consensus on the effects of combined or concurrent training on hypertensive older people's hemodynamic parameters.[16,17] This may be due to baseline blood pressure values and different manipulations of training variables. In this sense, contraction speed of resistance exercises, rest intervals between exercises and sets, protocol order (traditional RT or PT plus ET vs. ET plus traditional RT or PT), and different protocol structures (concurrent or combined training) may interfere with cardiovascular adaptations.

In this context, the order of exercises may influence the chronic physiological adaptations to training.[15,18,19] While previous studies have examined the effects of different exercise orders involving concurrent training on maximal dynamic strength, aerobic capacity, and muscle quality,[18,19] limited evidence is available regarding the effects of concurrent training comprising PT followed by ET versus ET followed by PT on arterial stiffness and hemodynamic parameters in older adults.

As a reduction in arterial stiffness in older women after ET or RT has been demonstrated,[20] it is essential to determine whether specific combinations or sequences of these modalities may further enhance improvements in the vascular health of hypertensive older adults. Additionally, as both PT and ET seem to increase nitric oxide production in older adults,[21,22] it is important to ascertain whether manipulating exercise order augments the production of this and other vasoactive substances involved in reducing arterial stiffness and improves hemodynamic parameters in this population.

Considering that arterial stiffness poses a risk of death, and that the manipulation of training variables can interfere with cardiovascular adaptations, more studies are needed to explore the effects of different combined and concurrent training protocols on arterial stiffness in hypertensive older adults. Thus, strength and conditioning professionals may have additional exercise training information and possibilities to improve cardiovascular health in this population.

Given the above, this study aimed to a) examine the effects of concurrent training on arterial stiffness and hemodynamic parameters in previously trained hypertensive older adults; and b) to investigate the effects of concurrent PT and ET exercise order on arterial stiffness and hemodynamic parameters in previously trained hypertensive adults.

METHODS

Study Design

This interventional, randomized study was conducted upon approval by the Ethics Committee at an institution affiliated with one of the authors. All participants signed an informed consent form after learning about the study approach and procedures they would undergo, and the potential risks and benefits. The study was conducted following the Helsinki Declaration of 1975.

Participants

The sample size calculation was utilizing G*Power software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany, version 3.1.9.4, 2019), adhering to Beck's recommendations.[23] The a priori sample size calculation was performed considering an ANOVA (F-test), $\alpha = 0.05$, power = 0.95, and a large effect size for PWV (arterial stiffness) ($\eta^2 p \geq 0.14$/ effect size f = 0.403).[12] Accordingly, 12 older adults per group would be needed. To account for possible dropouts, 13 participants were selected per group (Figure 1).

Inclusion criteria consisted of being 60 years old or above, able to walk with or without assistance, performing basic daily activities, having engaged in regular exercise training for the past six months, and clinically diagnosed with hypertension by a cardiologist. Exclusion criteria included experiencing disabling pain during exercise, inability to perform exercise sessions, and inability to participate in evaluations.

Thirty older adults were recruited by publicizing the project through digital media (e.g., Instagram). The 26 selected older adults were randomized with a computer-generated list of random numbers, and allocation concealment was ensured using opaque and sequentially numbered sealed envelopes. They were randomly assigned to the dynamic power training plus endurance training group (DPTETG) (n = 13) and the endurance training plus dynamic power training group (ETDPTG) (n = 13). The process plan is graphically depicted in Figure 1.

Experimental Approach to the Problem

After signing an informed consent form, participants visited the research facilities for familiarization with the experiment site, tests, and equipment used, as well as an explanation about the assessments and the exercise program.

All assessments (arterial stiffness, hemodynamic parameters, and body composition) were performed before and after 16 weeks of training by the same experienced exercise physiologists using identical procedures, blinded regarding group allocation. The experiments were performed in a quiet air-conditioned room (22° to 24°C) always in the morning (07:00 to 11:00 am) at the Laboratory of Assessment and Physiology of Ceuma University in four distinct phases.

During the initial phase (familiarization, two weeks), the exercises were applied to familiarize the participants with the initial and final positions of the exercises and concentric and eccentric movement speeds. The exercise professionals controlled the concentric and eccentric movement speed through verbal/tactile cues. To get familiarized with PT, participants performed two sets of six repetitions at an easy intensity, applying the rate of perceived exertion (RPE).[24,25] In addition, the target perceived exertion level during ET (walking) was set at an easy intensity on an adapted Borg Scale of 1–10.[26]

In the second phase (1 week), experienced exercise physiologists administered the initial assessments.

In the third phase (16 weeks), experienced strength and conditioning professionals assisted with the two protocols.

Lastly, in the fourth phase (1 week, after ending the protocols), experienced exercise physiologists administered the final assessments.

Assessment of Arterial Stiffness and Hemodynamic Parameters

Assessments of arterial stiffness and hemodynamic parameters were carried out in a quiet, air-conditioned room (22° to 24°C) during the morning hours in the Laboratory of Assessment and Physiology at Ceuma University, pre- and post-interventions. Participants were instructed to avoid exercise for 24 hours and abstain from caffeinated or alcoholic beverages for 24 hours before evaluations. Blood pressure (BP) was measured using a validated, automatic monitor (HEM-7130, Omron Healthcare Inc., Lake Forest, IL). During the assessment, participants were instructed to remain silent. The cuff was placed on the arm about 2 cm above the cubital fossa.[27] BP was measured three times on each side, with a 1-minute interval between each attempt.[27] When the identified difference between the sides is with a value > 10 mmHg in the first reading, new measurements were taken.[27] Otherwise, the first measurement was discarded, and the average of the last two measurements on each side was considered.[25] Additionally, the side with the highest average value was considered for the assessment pre- and post-intervention.[27] The arm with the highest BP values was used to assess central systolic blood pressure, central diastolic blood pressure, pulse pressure, central pulse pressure, and pulse wave velocity through of the triple pulse

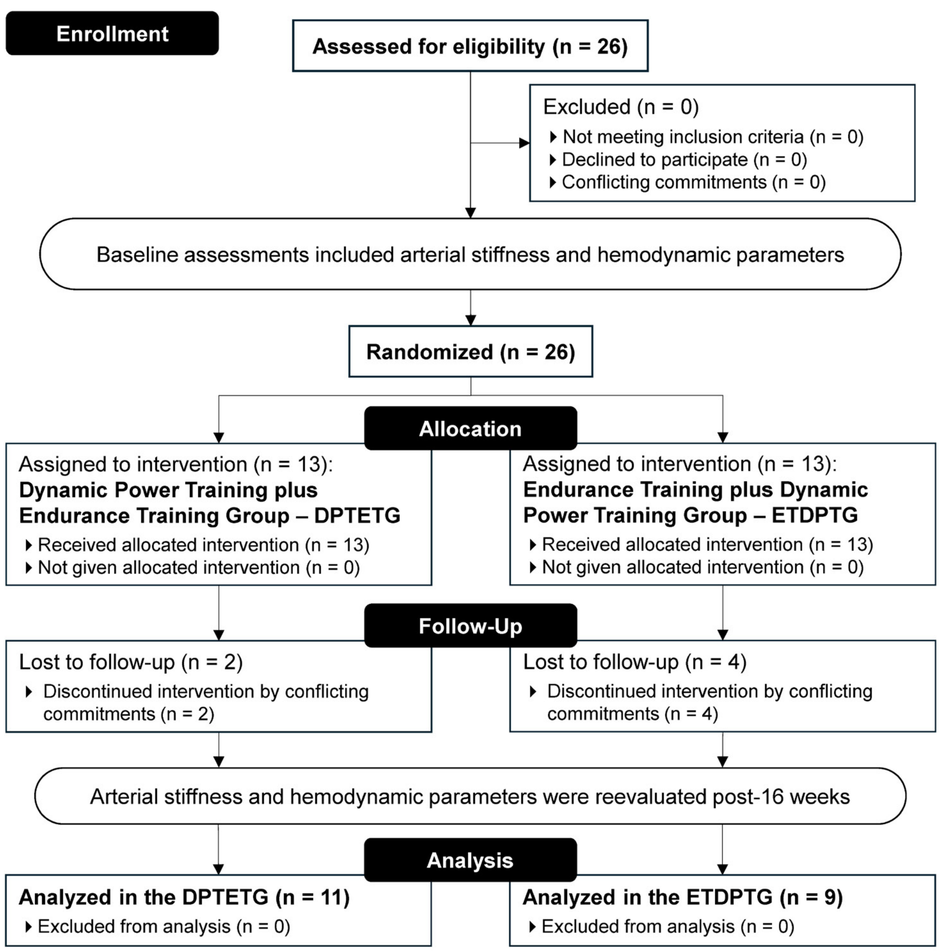

FIGURE 1. Flow diagram of participants

wave velocity method, by an automated oscillometric device (Arteris AOP, Cardio Sistemas Comercial Industrial Ltda, São Paulo, SP, Brazil).[12]

Interventions

Dynamic Power Training Plus Endurance Training Group (DPTETG)

The protocols were described following the recommendations of the Basic Guidelines for the Application of the Main Variables of RT in the Elderly.[28] PT was performed with free-weight, machine, and elastic bands (strong) (LIVEUP® SPORTS, Araucária, PR, Brazil).

During the main phase of the exercise program, training sessions were performed with moderate intensity according to RPE,[24-26] twice a week over 16 weeks, with a minimum 48-hour rest interval provided between each exercise session in the same week. The RPE was reported after the end of each set of exercises (PT and ET), and if the participant reported an RPE below the expectations (low intensity), the stimulus (weight, tension of the elastic band, and walking speed) was increased (moderate intensity).[24,25]

The exercises were performed at full amplitude, except for the squat (90°) and lateral elevation (90°) exercises, with concentric contractions performed as fast as possible, while the eccentric contractions were performed slowly within 3 seconds.

Protocol consisted of the following sequence (without intervals of absolute rest throughout the session). Participants did not perform the sequences in the same order.

1. Seated row (machine) interspersed with squat on the chair (free-weight);
2. Plantar flexion (machine) interspersed with squat on the chair (free-weight);
3. Bench press (free-weight) interspersed with squat on the chair (free-weight);
4. Knee extension (machine) interspersed with squat on the chair (free-weight);
5. Elbow flexion (machine) interspersed with squat on the chair (free-weight);
6. Leg curl (machine) interspersed with squat on the chair (free-weight);
7. Elbow extension (machine) interspersed with squat on the chair (free-weight);
8. Hip abduction (machine) interspersed with squat on the chair (free-weight);
9. Trunk flexion (elastic band) interspersed with squat on the chair (free-weight); and
10. Lateral elevation (free-weight) interspersed with squat on the chair (free-weight).

Endurance Training

Participants in both intervention groups (PTET and ETPT) will perform the same walking time. In the 16 weeks, both groups were walking at moderate intensity.[26] Exercise professionals were supervising each group of older adults to monitor them and control intensity, in the same format as the RT and PT monitoring (trainer/trainee ratio of 1:4).

The exercise training volume was increased over the 16 weeks, as shown below:

- First eight weeks: 1 set with 6 repetitions, combined with ~20 minutes of walking.
- Subsequent eight weeks: 1 set with 6 repetitions, combined with ~25 minutes of walking.

Endurance Training Plus Dynamic Power Training Group (ETDPTG)

Participants performed the same exercises as the DPTETG, starting with ET and ending with dynamic PT.

Statistical Analysis

Statistical analysis was conducted using Prism software (GraphPad Inc., San Diego, CA; Version 8.4.3, 2020). Descriptive statistics were analyzed using Bartlett's test, and normality was assessed with the Kolmogorov-Smirnov test. Mean values and standard deviations (SD) were calculated for each dependent variable. A two-way analysis of variance (ANOVA) with repeated measures on the "time" factor was used to evaluate the effects of the protocols ("group" × "time"). In cases where a significant interaction effect was observed, Bonferroni post hoc tests were used to identify within-group changes over time. Statistical significance was set at $p \leq .05$ for all analyses, which were two-tailed. Effect sizes (ES) were calculated using partial eta-squared ($\eta^2 p$) values, classified as small ($\eta^2 p \geq 0.01$), medium ($\eta^2 p \geq 0.06$), or large ($\eta^2 p \geq 0.14$) according to Espirito Santo and Daniel.[29]

RESULTS

Participants

In this study, 20 older adults diagnosed with grade 1 hypertension completed the pre- and post-16-week measurements and had their data included in the statistical analysis (ETDPTG: n = 9; DPTETG: n = 11). Their clinical characteristics are shown in Table 1.

Arterial Stiffness

There were no significant time effects, group effects, or time vs. group interaction in pulse wave velocity (PWV), pulse pressure, and central pulse pressure ($p > .05$) after 16 weeks of intervention (Table 2). Additionally, all participants in both groups had lower baseline PWV values than expected according to age and blood pressure levels.

Hemodynamic Parameters

There were no significant time effects, group effects, or time vs. group interaction in systolic blood pressure (SBP), diastolic blood pressure (DBP), central SBP, and central DBP ($p > .05$) after 16 weeks of intervention (Table 2).

DISCUSSION

The main finding of this study is that arterial stiffness did not decrease in hypertensive older adults after practicing different protocols (order of exercises) of concurrent PT. To our knowledge, this is the first study to investigate the effects of the order of exercises in concurrent power and endurance training on arterial stiffness and hemodynamic parameters in previously trained hypertensive older adults. This may have influenced the findings, considering that in all studies involving the benefits of concurrent or combined training, the sample consisted of older adults with no history of training for at least six months.[10-12,14,15]

TABLE 1.
Baseline clinical characteristics of the participants (n = 20)

Variables	*ETDPTG (n = 9)*	*DPTETG (n = 11)*	*P Value*
Age, years	71.7±8.0	70.7±7.5	.790
Body mass index, kg/m²	27.0±2.4	25.7±5.1	.486
Women, n (%)	7 (77.8)	9 (81.8)	.822
Associated Comorbidities (%)			
Hypertension	100	100	---
Diabetes mellitus type II	33.3	9.1	.178
Medications (%)			
Angiotensin receptor blockers	66.7	45.5	.343
Calcium channel blocker	22.2	---	.099
Diuretics	33.3	27.3	.769
Hypoglycemic agents	33.3	9.1	.178
Statins	44.4	54.5	.653

ETDPTG = Endurance Training plus Dynamic Power Training Group; DPTETG = Dynamic Power Training plus Endurance Training Group.

A study by our group demonstrated reduced arterial stiffness and improved hemodynamic parameters in hypertensive older adults after eight weeks of concurrent training (PT plus ET), although they had not trained for at least six months.[12] Likewise, previous studies have demonstrated the benefits of different concurrent training protocols on arterial stiffness of postmenopausal women and older adults with no history of exercise training for at least six months before starting the protocol.[14,15,30,31]

The reduction in arterial stiffness in older adults with and without hypertension and no history of training appears to occur in a short period (6-12 wks).[14,15,12] Hence, participants may have begun this study with positive adaptations from previous training. This can be evidenced by the individual PWV values (Figure 2). All participants in both groups had lower baseline PWV values than expected according to age and blood pressure levels, as observed in Figure 2. Further

TABLE 2.
Changes in arterial stiffness and hemodynamic parameters at baseline and after 16 weeks of intervention (n = 20)[a]

Variables	*ETDPTG (n = 9)*	*DPTETG (n = 11)*	*ETDPTG vs. DPTETG MD (95% CI)*	*P (η^2_p) values Group*	*Time*	*Interaction*
Pulse wave velocity (PWV) (m/s)				.252 (0.07)	.271 (0.07)	.296 (0.06)
Pre	10.2±1.2	10.2±1.1	0.0 (-4.2–22.2)			
Post	10.4±1.2	10.0±0.9	0.4 (-12.8–13.6)			
Central pulse pressure (cPP), mmHg				.186 (0.15)	.122 (0.13)	.894 (0.00)
Pre	35.4±10.1	39.3±5.7	-3.9 (-11.5–3.9)			
Post	32.4±5.5	35.7±7.3	-3.3 (-11.0–4.4)			
Pulse pressure (PP), mmHg				.152 (0.11)	.151 (0.11)	.664 (0.01)
Pre	47.6±12.7	50.4±7.1	-2.8 (-11.8–6.2)			
Post	42.2±4.9	47.5±8.1	-5.3 (-14.2–3.8)			
Systolic blood pressure (SBP), mmHg				.820 (0.00)	.123 (0.13)	.666 (0.01)
Pre	125.1±15.8	126.2±10.6	-1.1 (-14.3–12.1)			
Post	120.0±11.3	117.3±12.4	2.7 (-10.5–15.9)			
Diastolic blood pressure (DBP), mmHg				.090 (0.21)	.406 (0.04)	.340 (0.05)
Pre	77.6±9.4	74.5±7.8	3.1 (-6.4–12.6)			
Post	77.9±11.5	69.7±7.7	8.2 (-1.4–17.7)			
Central systolic blood pressure (CSBP), mmHg				.697 (0.01)	.170 (0.10)	.359 (0.05)
Pre	113.6±13.0	115.7±11.2	-2.1 (-14.8–10.4)			
Post	111.7±10.8	106.5±12.7	5.2 (-7.5–17.7)			
Central diastolic blood pressure (CDBP), mmHg				.110 (0.18)	.408 (0.04)	.322 (0.05)
Pre	78.1±8.5	75.6±7.9	2.5 (-6.9–11.8)			
Post	78.6±11.1	70.8±8.0	7.8 (-1.6–17.1)			

[a]Values are expressed as mean ± standard deviation.
ETDPTG = Endurance Training plus Dynamic Power Training Group; DPTETG = Dynamic Power Training plus Endurance Training Group; MD = mean difference; CI = confidence interval; η^2p = partial eta squared.

research with the same characteristics as the present study is needed to confirm this hypothesis.

Besides the lack of reduction in arterial stiffness, the present study did not find any improvement in hemodynamic parameters in hypertensive older adults. Although combining RT with ET provides several benefits for hypertensive older people's health,[16] there is still no consensus on the effects of concurrent and combined training on this population's arterial stiffness and blood pressure.[16,17]

Similarly, recent research by our group[10] found no improvement in blood pressure levels in previously trained older adults after practicing concurrent training protocols with

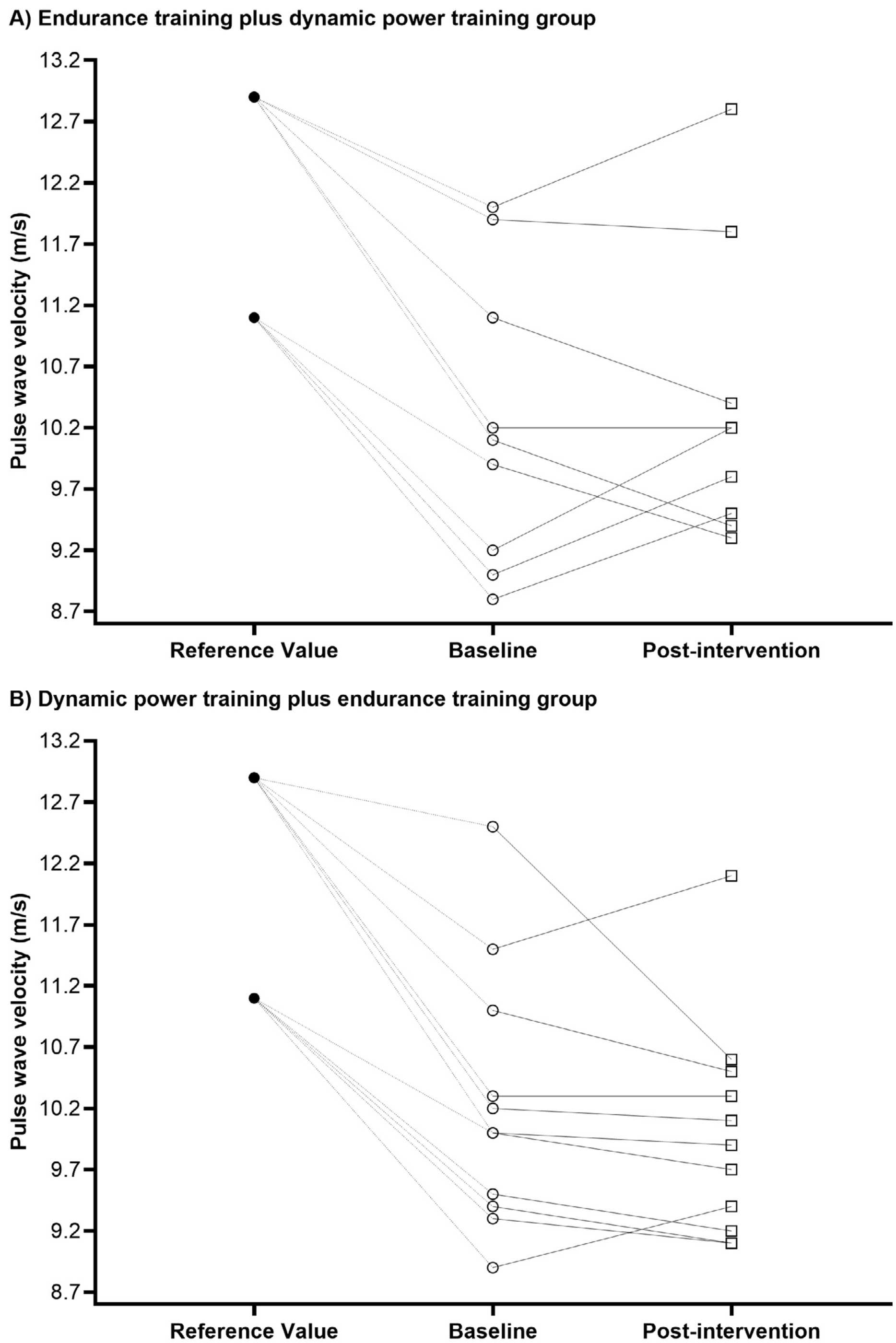

FIGURE 2. Pulse wave velocity (in meters per second) categorized by age and blood pressure levels (grade 1 hypertension), along with individual arterial stiffness values before and after the interventions; a pulse wave velocity (PWV) of 11.1 m/s is a reference value for individuals with grade 1 hypertension aged 60 to 69 years, while a PWV of 12.9 m/s is a reference value for those aged 70 years or older

different volumes. In this sense, studies involving exercise and blood pressure mostly involve older adults without prior exercise training.[12,32,33]

One hypothesis to explain our findings is the baseline blood pressure levels. Those participants in this research (ETDPTG: SBP; 125.1 ± 15.8 mmHg; DPTETG: SBP; 126.2 ± 10.6 mmHg) may justify the lack of statistical change in this variable. In the same sense, older adults with controlled blood pressure levels did not decrease after different concurrent training protocols.[10,33] The groups with repetitions to failure (120 ± 12 mmHg), repetitions not to failure (122 ± 12 mmHg), and repetitions not to failure with equalized volume (126 ± 15 mmHg) had SBP values close to those of the sample in this research.[33] Most studies observe the benefits of exercise in older adults with high blood pressure.[12,32,34]

In that regard, research by Sardeli *et al*.[17] indicates that baseline blood pressure values, rather than the type of exercise and age, primarily determined the blood pressure response to exercise, predicting 74 and 53% of the reductions in SBP and DBP, respectively. Another hypothesis for the lack of statistical change may be that the loss of participants, leaving a smaller sample, may have impacted the data analysis.

Although the present study did not demonstrate statistically significant changes in arterial stiffness and hemodynamic parameters in hypertensive older adults following different concurrent training protocols, the findings nonetheless present relevant clinical implications.

Considering that aging is associated with increased arterial stiffness, and that a 1 m/s rise in PWV is associated with 14%, 15%, and 15% increases in total cardiovascular events, cardiovascular mortality, and all-cause mortality, respectively,[35] a reduction of Δ = 0.2 m/s after the performance of PT combined with ET represents clinically meaningful potential for hypertensive older adults. In this regard, the observed reduction in present research (Δ = -0.2 m/s) is consistent with the findings of Park et al.,[36] who also reported an improvement in arterial stiffness (Δ = -0.2 m/s) following 12 weeks of concurrent training.

In addition, it found a significant clinical reduction in SBP in both groups (ETDPTG: SBP; Δ = -5.1 mmHg; DPTETG: SBP; Δ = -8.9 mmHg). These findings indicate a reduced risk of mortality from stroke and coronary artery disease.[37] Additionally, the DPTETG had a 4.8 mmHg reduction in DBP, which can prevent coronary heart disease and stroke events.[38]

Finally, the following study limitations stand out: the lack of a control group, participants of both sexes, time since hypertension diagnosis, different orders of exercises performed by participants, and the lack of maximum repetition testing to estimate the workload in each exercise. On the other hand, our findings may encourage further studies on this topic.

CONCLUSION

This study demonstrates that 16 weeks of different exercise orders of concurrent PT and ET do not change arterial stiffness and hemodynamic parameters in previously trained hypertensive older adults. On the other hand, no adverse effects were observed, even in the context of a cardiovascular risk condition such as arterial hypertension. Hence, we suggest further studies on the effects of different concurrent training protocols in older adults with quite abnormal arterial stiffness and high blood pressure.

ACKNOWLEDGEMENTS

The authors are grateful to the volunteers who participated in this study.

CONFLICT OF INTEREST DISCLOSURES

We have read and understood the *Canadian Geriatrics Journal*'s policy on conflicts of interest disclosure and declare that we have none.

FUNDING

This study will be financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brazil (CAPES) [under Finance Code 001] and was supported by Fundação de Amparo à Ciência e Tecnologia do Estado de Pernambuco (FACEPE) [grant numbers APQ-0246-4.06/14 and APQ-1413-4.08/21]. María Rúa-Alonso acknowledges the financial support received from the Xunta de Galicia (Consellería de Cultura, Educación, Formación Profesional y Universidades) through the Xunta de Galicia Postdoctoral Fellowships (ED481B-2024-077).

REFERENCES

1. Liu HW, Lee OK. Effects of resistance training with elastic bands on bone mineral density, body composition, and osteosarcopenic obesity in elderly women: a meta-analysis. J Orthop. 2024 Jul 1;53:168–75. doi: 10.1016/j.jor.2024.03.039
2. Gambassi BB, Dos Santos Júnior CR, Dos Santos AO, Rohrs EB, Novais TMG, Schwingel PA, *et al*. Resistance training maintains physical function but does not prevent changes in body composition and biochemical markers after detraining in aging adults. *J Bodyw Mov Ther*. 2024 Jan 1;37:146–50. doi: 10.1016/j.jbmt.2023.11.026
3. Gambassi BB, Rodrigues B, Feriani DJ, de Jesus Furtado Almeida F, Sauaia BA, Schwingel PA, *et al*. Effects of resistance training of moderate intensity on heart rate variability, body composition, and muscle strength in healthy elderly women. *Sport Sci Health*. 2016 Dec;12(3):389–95. doi: 10.1007/s11332-016-0303-z
4. Henkin JS, Pinto RS, Machado CLF, Wilhelm EN. Chronic effect of resistance training on blood pressure in older adults with prehypertension and hypertension: a systematic review and meta-analysis. *Exp Gerontol*. 2023 Jun 15;177:112193. doi: 10.1016/j.exger.2023.112193
5. Bouaziz W, Vogel T, Schmitt E, Kaltenbach G, Geny B, Lang PO. Health benefits of aerobic training programs in adults aged 70 and over: a systematic review. *Arch Gerontol Geriatr*. 2017 Mar 1;69:110–27. doi: 10.1016/j.archger.2016.10.012

6. Bouaziz W, Schmitt E, Vogel T, Lefebvre F, Remetter R, Lonsdorfer E, *et al*. Effects of interval aerobic training program with recovery bouts on cardiorespiratory and endurance fitness in seniors. *Scand J Med Sci Sports*. 2018 Nov;28(11):2284–92. doi: 10.1111/sms.13257
7. Carpes L, Costa R, Schaarschmidt B, Reichert T, Ferrari R. High-intensity interval training reduces blood pressure in older adults: a systematic review and meta-analysis. *Exp Gerontol*. 2022 Feb 1;158:111657. doi: 10.1016/j.exger.2021.111657
8. Izquierdo M, Merchant RA, Morley JE, Anker SD, Aprahamian I, Arai H, *et al*. International exercise recommendations in older adults (ICFSR): expert consensus guidelines. *J Nutr Health Aging*. 2021 Jul;25(7):824–53. doi: 10.1007/s12603-021-1665-8
9. Izquierdo M, de Souto Barreto P, Arai H, Bischoff-Ferrari HA, Cadore EL, Cesari M, *et al*. Global consensus on optimal exercise recommendations for enhancing healthy longevity in older adults (ICFSR). *J Nutr Health Aging*. 2025 Jan 1;29(1):100401. doi: 10.1016/j.jnha.2024.100401
10. Bavaresco Gambassi B, Cadore EL, Chaves LFC, da Silva Sousa TM, Mostarda CT, Lopes de Siqueira AF, *et al*. Effects of combined muscle power and endurance training with different volumes on functional and hemodynamic parameters in previously trained older adults. *Aging Clin Exp Res*. 2023 Nov;35(11):2623–31. doi: 10.1007/s40520-023-02572-y
11. Müller DC, Boeno FP, Izquierdo M, Aagaard P, Teodoro JL, Grazioli R, *et al*. Effects of high-intensity interval training combined with traditional strength or power training on functionality and physical fitness in healthy older men: a randomized controlled trial. *Exp Gerontol*. 2021 Jul 1;149:111321. doi: 10.1016/j.exger.2021.111321
12. Gambassi BB, Chaves LF, da Silva Sousa TM, Ribeiro MJ, Souza TA, Schwingel PA. Short-duration dynamic power training with elastic bands combined with endurance training: a promising approach to hypertension management in older adults. *J Hypertens*. 2024 Apr 1;42(4):735–42. doi: 10.1097/HJH.0000000000003681
13. Chaves LF, Gambassi BB, Cadore EL, Sotão S, Sousa TM, da Silva Dias D, *et al*. Power exercises with elastic bands combined with endurance training improve pulse pressure, systolic blood pressure, and functional parameters in older adults. *Blood Press Monit*. 2025 Apr 1;30(2):49–56. doi: 10.1097/MBP.0000000000000733.
14. Otsuki T, Namatame H, Yoshikawa T, Zempo-Miyaki A. Combined aerobic and low-intensity resistance exercise training increases basal nitric oxide production and decreases arterial stiffness in healthy older adults. *J Clin Biochem Nutr*. 2020;66(1):62–66. doi: 10.3164/jcbn.19-81
15. Shiotsu Y, Watanabe Y, Tujii S, Yanagita M. Effect of exercise order of combined aerobic and resistance training on arterial stiffness in older men. *Exp Gerontol*. 2018 Oct 1;111:27–34. doi: 10.1016/j.exger.2018.06.020
16. Sardeli AV, Griffth GJ, Dos Santos MV, Ito MS, Chacon-Mikahil MP. The effects of exercise training on hypertensive older adults: an umbrella meta-analysis. *Hypertens Res*. 2021 Nov;44(11):1434–43. doi: 10.1038/s41440-021-00715-0
17. Sardeli AV, Griffith GJ, Dos Santos MV, Ito MS, Nadruz W, Chacon-Mikahil MP. Do baseline blood pressure and type of exercise influence level of reduction induced by training in hypertensive older adults? A meta-analysis of controlled trials. *Exp Gerontol*. 2020 Oct 15;140:111052. doi: 10.1016/j.exger.2020.111052
18. Cadore EL, Izquierdo M, Alberton CL, Pinto RS, Conceição M, Cunha G, *et al*. Strength prior to endurance intra-session exercise sequence optimizes neuromuscular and cardiovascular gains in elderly men. *Exp Gerontol*. 2012 Feb 1;47(2):164–69. doi: 10.1016/j.exger.2011.11.013
19. Chtara M, Chamari K, Chaouachi M, Chaouachi A, Koubaa D, Feki Y, *et al*. Effects of intra-session concurrent endurance and strength training sequence on aerobic performance and capacity. *Br J Sports Med*. 2005 Aug 1;39(8):555–60. doi: 10.1136/bjsm.2004.015248
20. Lan YS, Khong TK, Yusof A. Effect of exercise on arterial stiffness in healthy young, middle-aged and older women: a systematic review. *Nutrients*. 2023 Jan 7;15(2):308. doi: 10.3390/nu15020308
21. Maeda S, Tanabe T, Otsuki T, Sugawara J, Iemitsu M, Miyauchi T, *et al*. Moderate regular exercise increases basal production of nitric oxide in elderly women. *Hypertens Res*. 2004 Dec;27(12):947–53. doi: 10.1291/hypres.27.947
22. Orsano VS, de Moraes WM, de Sousa NM, de Moura FC, Tibana RA, Silva AO, *et al*. Comparison of the acute effects of traditional versus high velocity resistance training on metabolic, cardiovascular, and psychophysiological responses in elderly hypertensive women. *Clin Interv Aging*. 2018 Jul 31;13:1331–40. doi: 10.2147/CIA.S164108
23. Beck TW. The importance of a priori sample size estimation in strength and conditioning research. *J Strength Cond Res*. 2013 Aug 1;27(8):2323–37. doi: 10.1519/JSC.0b013e318278eea0
24. Gearhart RF Jr, Lagally KM, Riechman SE, Andrews RD, Robertson RJ. Strength tracking using the OMNI resistance exercise scale in older men and women. *J Strength Cond Res*. 2009 May 1;23(3):1011–15. doi: 10.1519/JSC.0b013e3181a2ec41
25. Colado JC, Furtado GE, Teixeira AM, Flandez J, Naclerio F. Concurrent and construct validation of a new scale for rating perceived exertion during elastic resistance training in the elderly. *J Sports Sci Med*. 2020 Feb 24;19(1):175–86.
26. Borg G. Borg's perceived exertion and pain scales. Champaign (IL): Human Kinetics; 1988. 104 p.
27. Feitosa AD, Barroso WK, Mion Junior D, Nobre F, Mota-Gomes MA, Jardim PC, *et al*. Brazilian guidelines for in-office and out-of-office blood pressure measurement—2023. *Arq Bras Cardiol*. 2024;121(4):e20240113. doi: 10.36660/abc.20240113
28. Bavaresco Gambassi B, Lopes dos Santos MD, Furtado Almeida FJ. Basic guide for the application of the main variables of resistance training in elderly. *Aging Clin Exp Res*. 2019Jul 1;31(7):1019-–20. doi: 10.1007/s40520-019-01181-y
29. Espirito Santo HM, Daniel F. [Calculating and reporting effect sizes on scientific papers (3): guide to report regression models and ANOVA effect sizes]. Rev Port Inv Comport Soc. 2018 Feb 1;4(1):43–60. doi: 10.7342/ismt.rpics.2018.4.1.72
30. Figueroa A, Park SY, Seo DY, Sanchez-Gonzalez MA, Baek YH. Combined resistance and endurance exercise training improves arterial stiffness, blood pressure, and muscle strength in postmenopausal women. *Menopause*. 2011 Sep 1;18(9):980–84. doi: 10.1097/gme.0b013e3182135442
31. Son WM, Sung KD, Cho JM, Park SY. Combined exercise reduces arterial stiffness, blood pressure, and blood markers for cardiovascular risk in postmenopausal women with hypertension. *Menopause*. 2017 Mar 1;24(3):262–68. doi: 10.1097/GME.0000000000000765
32. Roberson KB, Potiaumpai M, Widdowson K, Jaghab AM, Chowdhari S, Armitage C, *et al*. Effects of high-velocity circuit

resistance and treadmill training on cardiometabolic risk, blood markers, and quality of life in older adults. *Appl Physiol Nutr Metab*. 2018;43(8):822–32. doi: 10.1139/apnm-2017-0807

33. Mota MR, de Oliveira RJ, Dutra MT, Pardono E, Terra DF, Lima RM, *et al*. Acute and chronic effects of resistive exercise on blood pressure in hypertensive elderly women. *J Strength Cond Res*. 2013 Dec 1;27(12):3475–80. doi: 10.1519/JSC.0b013e31828f2766
34. Dos Santos ES, Asano RY, Irñnio Filho G, Lopes NL, Panelli P, Nascimento DD, *et al*. Acute and chronic cardiovascular response to 16 weeks of combined eccentric or traditional resistance and aerobic training in elderly hypertensive women: a randomized controlled trial. *J Strength Cond Res*. 2014 Nov 1;28(11):3073–84. doi: 10.1519/JSC.0000000000000537
35. Vlachopoulos C, Aznaouridis K, Stefanadis C. Prediction of cardiovascular events and all-cause mortality with arterial stiffness: a systematic review and meta-analysis. *J Am Coll Cardiol*. 2010 Mar 30;55(13):1318–27. doi: 10.1016/j.jacc.2009.10.061
36. Park W, Jung WS, Hong K, Kim YY, Kim SW, Park HY. Effects of moderate combined resistance- and aerobic-exercise for 12 weeks on body composition, cardiometabolic risk factors, blood pressure, arterial stiffness, and physical functions, among obese older men: a pilot study. *Int J Environ Res Public Health*. 2020 Oct 3;17(19):7233. doi: 10.3390/ijerph17197233
37. Whelton PK, He J, Appel LJ, Cutler JA, Havas S, Kotchen TA, *et al*. Primary prevention of hypertension: clinical and public health advisory from The National High Blood Pressure Education Program. *JAMA*. 2002 Oct 16;288(15):1882–88. doi:10.1001/jama.288.15.1882
38. Cook NR, Cohen J, Hebert PR, Taylor JO, Hennekens CH. Implications of small reductions in diastolic blood pressure for primary prevention. *Arch Intern Med*. 1995 Apr 10;155(7):701–09.

Correspondence to: Bruno Bavaresco Gambassi, PhD, Ceuma University, Department of Physical Education, São Luís, MA, Brazil. Address: Rua Josué Montello, 1 - Renascença II, São Luís - MA, 65075-120, Brazil
E-mail: professorbrunobavaresco@gmail.com