Combined exercise training in asymptomatic elderly with controlled hypertension: Effects on functional capacity and cardiac diastolic function

Gabriel N. Guirado, Ricardo L. Damatto, Beatriz B. Matsubara, Meliza G. Roscani, Danieliso R. Fusco, Luiz A.F. Cicchetta, Marcos M. Seki, Altamir S. Teixeira, Adriana P. Valle, Katashi Okoshi, Marina P. Okoshi

Department of Internal Medicine, Botucatu Medical School, Sao Paulo State University, UNESP, SP, Brazil

Source of support: CNPq (310547/2006-7 and 305013/2009-0) and FundUNESP (00779/07-DFP)

Summary

Background: Aging is associated with changes in cardiac structure and function that are associated with left ventricular diastolic dysfunction. Whether diastolic functional alterations during senescence are manifestations of the intrinsic aging process or related to cardiac adaptations to a more sedentary lifestyle is still unsettled. This was a prospective study evaluating the effects of a 6-month combined exercise training period on functional capacity and diastolic function in sedentary elderly patients with controlled arterial hypertension.

Material/Methods: Functional capacity was assessed by exercise stress test and muscle strength was evaluated by the one-repetition maximum test. Cardiac structures and function were analyzed by transthoracic echocardiography.

Results: Fifteen patients, 68±8 years old, completed the training program. Exercise training significantly improved physical capacity (distance walked: 551±92 vs. 630±153 m, \( P < 0.05 \); work load: 7.2±1.7 vs. 8.5±3.0 METs, \( P < 0.05 \)) and upper and lower extremity muscle strength (\( P < 0.001 \)). Arterial blood pressure significantly decreased after training (systolic blood pressure: 134±9 vs. 128±8 mmHg; diastolic blood pressure: 82±7 vs. 77±6 mmHg; \( P < 0.05 \)). Cardiac structures and left and right systolic and diastolic function did not change after combined training (\( P > 0.05 \)).

Conclusions: Combined and supervised training for a 6-month period increases physical capacity and muscle strength in elderly patients with controlled arterial hypertension without changing resting left ventricular diastolic function.

key words: aging • arterial hypertension • diastolic function • echocardiogram • exercise • functional capacity

Full-text PDF: http://www.medscimonit.com/fulltxt.php?ICID=883215

Word count: 2026

Tables: 5

Figures: –

References: 35

Author’s address: Marina Politi Okoshi, Departamento de Clinica Medica, Faculdade de Medicina de Botucatu, UNESP, Rubiao Junior, S/N, 18618 970 Botucatu, SP, Brazil, e-mail: mpoliti@fmb.unesp.br
BACKGROUND

Aging is associated with changes in cardiac and vascular structure and function that occur in apparently healthy individuals [1]. These alterations are associated with left ventricular (LV) diastolic dysfunction, which is commonly observed in the elderly and is responsible for diastolic heart failure syndrome [1]. Whether diastolic functional alterations with senescence are manifestations of the intrinsic aging process or are related to cardiac adaptations to a more sedentary lifestyle is still unsettled [2–4]. During aging, there is usually a progressive reduction in physical activity. Although physical training programs are currently part of recommendations for disease prevention and cardiac rehabilitation [5–8], their effects on LV diastolic function of elderly individuals are still unclear. Most available data have come from studies with elderly who have been involved in sports competitions for periods of at least 10 years [2,4,9–11]. In these studies, although some authors did not find a long-term training-induced modulation of diastolic function [10–13], there is substantial evidence that regular and intense aerobic-endurance exercise prevents or attenuates LV diastolic functional changes associated with aging [2,4,9]. Only a few studies have evaluated the effects of exercise initiated at an elderly age on diastolic function in healthy individuals [14,15] or heart failure patients [14]. We did not find any studies evaluating the effects of exercise on diastolic function in patients with systemic arterial hypertension. Increased blood pressure, a highly prevalent condition in the elderly, negatively modulates diastolic function. In this study we evaluated the effects of combined exercise training on functional capacity and diastolic function in sedentary elderly patients with controlled arterial hypertension.

MATERIAL AND METHODS

Subjects

Elderly sedentary patients with controlled arterial hypertension, aged between 60 and 85 years, were recruited from a geriatric unit at the University Hospital, Botucatu Medical School, Sao Paulo State University, UNESP. Arterial hypertension was considered controlled when systolic and diastolic blood pressures were lower than 140 mmHg and 90 mmHg, respectively. Exclusion criteria included stage C heart failure, heart valve disease, coronary artery disease or exercise stress test results suggesting ischemic heart disease, previous stroke, diabetes mellitus, cardiac arrhythmia, and cognitive impairment or other conditions that could restrict physical activities such as musculoskeletal disorders or peripheral vascular disease. Physical activity level was assessed by interview. Patients were considered sedentary when not involved in regular programs of physical exercise or recreational physical activities in the last 3 months [17]. All procedures were approved by the Research Ethics Committee of Botucatu Medical School.

At the start and end of a 6-month training program, patients were subjected to the following evaluation: medical history and physical examination, transthoracic Doppler-echocardiogram, exercise stress test, and skeletal muscle strength evaluation.

Clinical evaluation

Medical history and physical examination were performed to assess general health and to clinically exclude diseases or conditions described in the exclusion criteria. Blood pressure was measured by the auscultatory technique with a conventional mercury sphygmomanometer [6].

Echocardiography

A standard echocardiography system (General Electric Medical Systems, Vivid S6, Tirit Carmel, Israel) was used to measure cardiac structures according to American Society of Echocardiography recommendations [18]. LV structures were measured by two-dimensional guided M-mode images. LV mass (LVM) was calculated using the formula:

$$LVM = 0.8 \times (1.04 \times [(LVDd + PWTd + SWTd)^{3/2} - (LVDd)^{3}]) + 0.6$$

where LVDd, PWTd, and SWTd are LV diameter, posterior wall thickness, and septal thickness at end diastole, respectively. Biplane modified Simpson’s method was used for measurement of left atrial (LA) volume at ventricular end systole. LV ejection fraction was obtained by bi-plane Simpson’s method. Right ventricular area was measured by planimetry in the apical four-chamber view. Left and right ventricular diastolic function was evaluated by spectral pulsed Doppler and tissue Doppler imaging [20,21].

Exercise stress test

The maximum exercise stress test was performed according to a modified Bruce protocol. Maximal oxygen consumption (MVO$_{\text{2}}$) was calculated as follows:

$$\text{MVO}_{2} = (1.8 \times \text{speed} \times [(0.073 + \text{inclination})/100]) / 3.5.$$

Maximal skeletal muscle strength assessment

Maximal muscular strength was evaluated using the voluntary 1 repetition maximum (1RM) test for 6 different resistance exercises: pull down, bench press, biceps curl, triceps extension, leg extension, and horizontal leg press.

Exercise training

The exercise program consisted of combined aerobic and strength training over a 6-month period. Training was performed on 3 days a week with at least 1 day of rest between sessions. Each training session started with a 5-minute warm-up and stretching followed by 30 minutes of walking. The intensity of aerobic exercise was 60% to 75% of heart rate reserve (HHr), which was calculated according to the formula:

$$HHr = HRmax - (HRmax - HRrest) \times \text{xwork intensity (‰)}$$

where HRrest is the rest heart rate and HRmax is the maximal heart rate reached during exercise stress test. In all sessions, heart rate was monitored with a frequency-meter (Polar, FS1, Finland). Strength training was performed in resistance exercise machines with 3 series of 8–12 repetitions of 60% of 1RM for each trained muscle or muscle group. After 3 weeks of training, 1RM was re-evaluated and workload adapted to ensure training was still performed at 60% of 1RM.

Statistical analysis

Variables are presented as mean and standard deviation or median and minimum and maximum values. Comparisons between periods were performed by Student’s $t$ test for
dependent data for variables with normal distribution and by Wilcoxon test for variables with a non-normal distribution. The level of significance was 5%.

**RESULTS**

**Participants**

Sixteen sedentary elderly individuals were included in the study (10 women and 6 men) and 15 (68±8 years old) completed the 6-month training program. All patients were asymptomatic at clinical cardiovascular and respiratory assessment. In the 3 months leading up to the study, all patients were clinically stable on medical therapy and no changes in medicines or drug doses were performed during the training period. The effects of exercise training on LV diastolic function in elderly hypertensive patients. Two patients presented unspecific alterations in ventricular repolarization. Exercise stress tests performed before and after training showed no evidence of myocardial ischemia or cardiac arrhythmia. The training program induced a significant increase of test duration, walking distance, and calculated MVO₂ and metabolic equivalent rate (Table 2).

**Echocardiographic evaluation**

Cardiac structural and functional variables are shown in Tables 3–5. One patient had concentric LV hypertrophy in both periods. Abnormalities of left ventricular relaxation, characterized by a decreased E/A ratio (<0.9) and/or an increased mitral E-wave deceleration time (EDT >240 ms), were observed in 11 patients at baseline and in 15 after training. These patients were classified as presenting diastolic dysfunction grade I, also called mild diastolic dysfunction [23]. No patient presented moderate or severe diastolic dysfunction. The combined training did not statistically change cardiac parameters analyzed by transthoracic echocardiography.

**DISCUSSION**

In this study we evaluated the effects of supervised combined physical training over a 6-month period on functional capacity and LV diastolic function in sedentary elderly individuals with controlled systemic arterial hypertension.

The effects of physical training on LV diastolic function during aging have been poorly addressed in the literature. Most studies have compared sedentary elderly individuals with those involved in aerobic competitive training programs for periods of at least 10 years [2,4,9–11]. Furthermore, only a few authors have analyzed the effects of combined endurance and strength training on LV diastolic function in sedentary elderly individuals [14]. Concerning arterial hypertension, although there are numerous studies on the effects of exercise on blood pressure control [5,24,25], we did not find any studies specifically evaluating the role of combined exercise on LV diastolic function in elderly hypertensive patients.

In this study, the exercise protocol was based on recommendations [5,6,25,26] to combine aerobic and resistance

---

**Table 1. General characteristics of participants.**

|                          | Baseline       | After-training |
|--------------------------|----------------|---------------|
| Body weight (kg)         | 74±15          | 74±15         |
| BMI (kg/m²)              | 30±1.8         | 30±1.7        |
| SBP (mmHg)               | 134±9          | 128±8*        |
| DBP (mmHg)               | 82±7           | 77±6*         |
| HR (bpm)                 | 73±10          | 70±10         |

BMI – body mass index; SBP – systolic blood pressure; DBP – diastolic blood pressure; HR – resting heart rate; bpm: beats per minute; * P<0.05 vs. Baseline. Student’s t test for dependent data.

**Table 2. Physical capacity evaluated by the exercise stress test (modified Bruce protocol).**

|                          | Baseline       | After-training |
|--------------------------|----------------|---------------|
| Test duration (min)      | 9.29±2.90      | 11.41±2.22*   |
| Distance walked (m)      | 551±92         | 630±153*      |
| VO₂ max (ml/kg/min)      | 24±7           | 28±9*         |
| HR max (bpm)             | 141±14         | 146±13        |
| SBP max (mmHg)           | 171±20         | 179±21        |

Double product (mmHg.bpm) 24,201±4,352 26,202±3,552

Work load (METs)          7.2±1.7

VO₂ max – maximum oxygen consumption; HR max – maximum heart rate reached; bpm – beats per minute; SBP max – maximum systolic blood pressure reached; MET – metabolic equivalent rate; * P<0.05 vs. Baseline; Student t test for dependent data.
Training program attendance was adequate, as all patients attended more than 85% of training sessions. To ensure that patients were properly exercised, we evaluated functional exercises for non-pharmacological treatment of hypertension. Evidence that strength training is important for maintaining health and preventing cardiovascular diseases began to be published only in the 1990’s [5,14,27–29]. Therefore, to date there have been few studies evaluating the effects of resistive exercise on blood pressure control. In a recent meta-analysis [25], the authors only identified 3 trials conducted in hypertensive patients and, therefore, no reliable conclusions could be drawn for those patients. In our study, combined training induced a statistically significant decrease in systolic and diastolic blood pressure. However, as we did not have a control group without training, we cannot discard the influence of variables such as the familiarity of individuals with medical staff in reducing blood pressure.

Training program attendance was adequate, as all patients attended more than 85% of training sessions. To ensure that patients were properly exercised, we evaluated functional capacity and muscle strength before and after the training period. The exercise stress test showed an improvement in functional capacity characterized by increased walked distance, test duration, and calculated metabolic equivalent rate and maximum oxygen consumption. Although measurement of oxygen consumption is considered to be the best parameter for assessing physical capacity, the calculated metabolic equivalent rate has been widely accepted as a clinical tool for determining functional capacity relevant to daily activities [30]. As expected, combined training significantly increased the 1RM values for all muscle strength variables. The increase was higher than commonly reported for geriatric populations, probably due to our long-term training protocol – 6 months – compared to other studies which evaluated individuals after training for 3 [14] or 4 months [31].

Despite an improvement in physical capacity, LV diastolic function remained unchanged after the training period. As previously mentioned, many authors have assessed the effects of exercise on diastolic function in elderly athletes involved in sport competitions for long periods of time [2,4,9,11,32]. Most studies have shown that prolonged and intensive training can preserve diastolic function in healthy elderly individuals by preventing its decay during the course of aging [2,4]. However, the effects of exercise on diastolic function in sedentary healthy elderly individuals have not been clearly defined. Haykowsky et al. [14] found unchanged diastolic function in healthy elderly women after different exercise protocols for 12 weeks. On the other hand, healthy elderly individuals subjected to intense aerobic training for 6 months presented enhanced early diastolic filling at rest and during exercise [15]. In elderly patients with diastolic heart failure,
physical training increased maximum oxygen consumption without changing ventricular diastolic function [16].

Experimental studies have shown that exercise ameliorates calcium transport by the cardiac sarcomplasmic reticulum and myocardial relaxation [33,34]. We therefore could have expected improved diastolic function in our patients. However, as myocardial aging is characterized by structural changes such as myocyte loss followed by fibrous tissue replacement and hypertrophy of remaining myocytes [1], it is understandable that these changes are unlikely to be reversed by physical or pharmacological measurements.

One limitation of this study is that diastolic function was assessed at rest. Diastolic dysfunction has been found during exercise in patients with unchanged diastolic function at rest [35]. Thus, it is possible that during exercise and increased heart rate, our patients did present improved diastolic function following exercise training. Finally, as our sample size was small, additional studies are needed to confirm our results.

CONCLUSIONS

Combined and supervised training for a 6-month period increases physical capacity and muscle strength in elderly patients with controlled arterial hypertension without changing resting left ventricular diastolic function.

Acknowledgments

The authors are grateful to Colin Edward Knnags for English editing.

REFERENCES:

1. Lakatta EG, Levy D: Arterial and cardiac aging: major shareholders in cardiovascular disease enterprises. Part II: The aging heart in health: links to heart disease. Circulation, 2003; 107: 546–54
2. Prasad A, Popović ZB, Arbab-Zadeh A et al: The effects of aging and physical activity on doppler measures of diastolic function. Am J Cardiol, 2007; 99: 1629–36
3. Palka P, Lange A, Nihoyannopoulos P: The effect of long-term training on age-related left ventricular changes by Doppler myocardial velocity gradient. Am J Cardiol, 1999; 84: 1061–67
4. Arbab-Zadeh A, Dijk E, Prasad A et al: Effect of aging and physical activity on left ventricular compliance. Circulation, 2004; 110: 1799–805
5. Braith RW, Stewart KJ: Resistance exercise training: its role in the prevention of cardiovascular disease. Circulation, 2006; 113: 2642–50
6. Mancia G, De Backer G, Dominiczak A et al: 2007 Guidelines for the management of arterial hypertension. The task force for the management of arterial hypertension of the European society of hypertension (ESH) and the European Society of Cardiology (ESC). Eur Heart J, 2007; 28: 1462–536
7. Thompson PD: Exercise-based, comprehensive cardiac rehabilitation. In: Libby P, Bonow RO, Mann DL, Zipes DP (eds.), Braunwald’s Heart Disease. A textbook of cardiovascular medicine. Philadelphia Saunders Elsevier, 2008; 11: 449–55
8. Kolovou G, Marvaki A, Bilianou H: One more look at guidelines for primary and secondary prevention of cardiovascular disease in women. Arch Med Sci, 2011; 7: 747–55
9. Galetz F, Franzoni F, Femia FR et al: Left ventricular diastolic function and carotid artery wall in elderly athletes and sedentary controls. Biomed Pharmacother, 2004; 58: 437–42
10. Gates PE, Tanaka H, Graves J, Seals DR: Left ventricular structure and diastolic function with human aging. Relation to habitual exercise and arterial stiffness. Eur Heart J, 2003; 24: 2215–20
11. Notton S, Nguyen LD, Terbath M, Obert P: Long-term endurance training does not prevent the age-related decrease in left ventricular relaxation properties. Acta Physiol Scand, 2004; 181: 209–15
12. Baldi JC, McFarlane K, Owenham HC et al: Left ventricular diastolic filling and systolic function of young and older trained and untrained men. J Appl Physiol, 2003; 95: 2570–75
13. Fleg JL, Shapiro EP, O’Connor F et al: Left ventricular diastolic filling performance in older male athletes. JAMA, 1993; 273: 1371–75
14. Haykowsky M, McGaw J, Muhl IV et al: Effect of exercise training on peak aero- power, left ventricular morphology, and muscle strength in healthy older women. J Gerontol, 2005; 60A: 307–11
15. Levy WC, Cerqueira MD, Abrass IB et al: Endurance exercise training augments diastolic filling at rest and during exercise in healthy young and older men. Circulation, 1995; 98: 116–26
16. Smart N, Halaska B, Jeffries L, Marswick TH: Exercise training in systolic and diastolic dysfunction: effects on cardiac function, functional capacity, and quality of life. Am Heart J, 2007; 153: 530–36
17. Warren JM, Ekelund U, Bessom H et al: Assessment of physical activity – a review of methodologies with reference to epidemiological research: a report of the exercise physiology section of the European Association of Cardiovascular Prevention and Rehabilitation. Eur J Cardiovasc Prev Rehabil, 2010; 17: 127–39
18. Lang RM, Bierg M, Devereux RB et al: Recommendations for chamber quantification: a report from the American Society of Echocardiography’s Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr, 2005; 18: 1440–63
19. Devereux RB, Alonso DR, Lutas EM et al: Echocardiographic assessment of left ventricular hypertrophy: comparison to necropsy findings. Am J Cardiol, 1986; 57: 450–58
20. Loo Y, Pan YZ, Zeng C et al: Altered serum creatine kinase level and cardiac function in ischemia-reperfusion injury during percutaneous coronary intervention. Med Sci Monit, 2011; 17(9): CR174–79
21. Celik A, Sahin S, Kor F et al: Cardiophotroph-1 plasma levels are increased in patients with diastolic heart failure. Med Sci Monit, 2012; 18(1): CR25–31
22. Warburton DER, Nicol GW, Bredin SSD: Prescribing exercise as preventive therapy. Can Med Assoc J, 2006; 174: 961–74
23. Lester SJ, Tajik AJ, Nishimura RA et al: Unlocking the mysteries of diastolic function. Depicting the Rosetta stone 10 years later. J Am Coll Cardiol, 2008; 51: 679–89
24. Cornelissen VA, Fagard RH: Effect of resistance training on resting blood pressure: a meta-analysis of randomized controlled trials. J Hypertens, 2005; 25: 251–59
25. Fagard RH, Cornelissen VA: Effect of exercise on blood pressure control in hypertensive patients. Eur J Cardiovasc Prevention Rehabil, 2007; 14: 12–17
26. Pollock ML, Franklin BA, Balady GJ et al: Resistance exercise in individuals with and without cardiovascular disease. Benefits, rationale, and prescription. An advisory from the committee on exercise, rehabilitation, and prevention, council on cardiovascular medicine, American Heart Association. Circulation, 2000; 101: 828–35
27. Fagard RH: Exercise is good for your blood pressure: effects of endurance training and resistance training, Clin Exp Pharmacol Physiol, 2006; 33: 53–56
28. Wood RH, Reyes R, Welch MA et al: Concurrent cardiovascular and resistance training in healthy older adults. Med Sci Sports Exerc, 2001; 33: 1571–58
29. Delagardelle C, Feiereisen P, Autier P et al: Strength training versus endurance training in congestive heart failure. Med Sci Sports Exerc, 2002; 34: 1868–72
30. Greswalt J, McCully RB, Kane GC et al: Left ventricular function and exercise capacity. JAMA, 2009; 301: 860–861
31. Haykowsky M, Humen D, Teo K et al: Effects of 16 weeks of resistance training on left ventricular morphology and systolic function in healthy men 160 years of age. Am J Cardiol, 2009; 85: 1002–6
32. Gates PE, Seals DR: Decline in large elastic artery compliance with age. Circulation, 1990; 258: H431–35
33. Brenner DA, Apstein CS, Snape KW: Exercise training attenuates age-associated diastolic dysfunction in rats. Circulation, 2001; 104: 221–26
34. Tate CA, Taffet GE, Husbon EK et al: Enhanced calcium uptake of cardiac sarcomplasmic reticulum in exercise-trained old rats. Am J Physiol, 1990; 258: H131–35
35. Salimian AM, Frost P, Dancy M: Impaired left ventricular diastolic function during isometric exercise in asymptomatic patients with hyperlipidemia. Int J Cardiol, 2004; 95: 275–80