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

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A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
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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**

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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, Tirat 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:

$$LVM=0.8\times\{1.04[(LVDd+PWTd+SWTd)^3-(LVDd)^3]\}+0.6 \ [19],$$

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_2) was calculated as follows:

$$MVO_2=\{1.8 \times speed \times [(0.073 + inclination)/100]\}/3.5.$$

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=HRrest+(HRmax-HRrest)xwork intensity (%) [22], 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

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*
VO_2 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	8.5±3.0*

VO_2 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.

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 subjects who completed the exercise program had been taking the following medicines: angiotensin-converting enzyme inhibitor (n=11, 73%), diuretics (n=7, 47%), statins (n=5, 33%), calcium channel blockers (n=2, 13%), angiotensin antagonist receptor (n=2, 13%), oral hypoglycemic agent, hypouricemiant, cholesterol absorption inhibitor, and anti-arrhythmic agent (n=1, 7%). All individuals reported no regular cigarette smoking within the previous 4 years. Adherence to the program was 88.4±4.2% and all individuals attended more than 85% of the training sessions.

General characteristics of patients at baseline and post-training periods are presented in Table 1. Body weight, body mass index, and resting heart rate did not change after physical training. Systolic and diastolic arterial blood pressure was significantly reduced after completing the training protocol.

Maximal muscular strength

There was a significant increase in skeletal muscle strength in all trained muscles or muscle groups. For exercises performed with the arms, increases in 1RM values were as follows: pull down 40%, supino 57%, biceps curl 50%, and triceps extension 34%. For lower limb exercises, leg extension and horizontal leg press, increases of 1RM values were 47% and 100%, respectively.

Exercise stress test

Electrocardiograms recorded at rest showed no evidence of myocardial ischemia, arrhythmia, or heart chambers hypertrophy. 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 MVO_2 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 13 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 3. Structural cardiac indices assessed by transthoracic echocardiography.

	Baseline	After-training
LVDd (mm)	46.2±3.9	45.5±3.6
LVSD (mm)	26.5±3.8	25.6±2.6
SWTd (mm)	9.77±1.46	9.59±1.32
PWTd (mm)	9.17±1.39	9.25±1.20
LVM (g)	155±40	151±36
LVM/BSA (g/m^2)	87±16	84±13
LAV/BSA (ml/m^2)	25.9±10.9	25.4±6.1
RVDA (cm^2)	17.9±5.3	19.1±3.6
RVSA (cm^2)	9.50±2.99	10.28±2.02

LVDd – left ventricular (LV) end-diastolic diameter; LVSd – LV end-systolic diameter; SWTd – septal wall thickness at end diastole; PWTd – posterior wall thickness at end diastole; LVM – LV mass; BSA – body surface area; LAV – left atrial volume; RVDA – right ventricular (RV) diastolic area; RVSA – RV systolic area; Student *t* test for dependent data.

Table 4. Left and right ventricular systolic functional indices assessed by transthoracic echocardiography.

	Baseline	After-training
HR (bpm)	70.6±9.9	68.9±7.3
LVFS (%)	42.8±5.2	43.8±3.5
LVEF	0.61±0.10	0.58±0.07
CO (l/min)	4.17±0.66	4.17±0.71
RV ΔA (%)	46.5±8.0	46.1±9.8

HR – heart rate; bpm – beats per minute; LVFS – left ventricular (LV) fractional shortening; LVEF – LV ejection fraction; CO – cardiac output; RV ΔA – right ventricular fractional area change. Student *t* test for dependent data.

Table 5. Left and right ventricular diastolic function indices assessed by transthoracic echocardiography.

	Baseline	After-training
LV E (cm/s)	73±20	69±9
LV A (cm/s)	88±15	91±15
LV E/A	0.84±0.23	0.77±0.09
LV IVRT (ms)	113±22	109±14
LV EDT (ms)	222±48	250±50
LV E′ (cm/s)	9.10±3.64	10.06±2.75
LV A′ (cm/s)	10.32±3.20	12.65±4.01
LV E/E′	8.68±3.03	7.38±2.26
LV E′/A′	0.96±0.44	0.82±0.17
RV E (cm/s)	48±13	49±11
RV A (cm/s)	45±10	50±12
RV E/A	1.09±0.37	1.01±0.28

LV E – early mitral inflow velocity; LV A – late mitral inflow velocity; LV E/A – ratio of early and late mitral valve flow velocity; LV IVRT – left ventricular (LV) isovolumic relaxation time; LV EDT – mitral E-wave deceleration time; LV E′ – early diastolic mitral annular velocity; LV A′ – late diastolic mitral annular velocity; RV E – early tricuspid inflow velocity; RV A – late tricuspid inflow velocity. Student *t* test for dependent data.

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 intense 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 sarcoplasmic 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.

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