Original Article

Cardiopulmonary Responses to Exercise in Patients of Different Age Group with Congestive Heart Failure

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Objectives

This paper aims at comparing cardiorespiratory functional capacity during exercise - represented by indicators of functional limitation, maximal oxygen uptake (VO_2max), and anaerobic threshold – plus cardiopulmonary responses to maximal exercise in congestive heart failure (CHF) patients belonging to different age groups.

Methods

Fifty-four CHF patients, stratified by age group, were evaluated as follows: group I – 30 to 39 years (n = 12); group II – 40 to 49 years (n = 18); group III – 50 to 59 years (n = 17); and group IV – 60 years and above (n = 7). All patients underwent maximal cardiopulmonary exercise testing (CPET) on treadmills. A single-factor analysis of variance (ANOVA) was performed to compare different age groups.

Results

No significant differences were found in maximal oxygen uptake and anaerobic threshold among the age groups, nor in maximal values for carbon dioxide production, oxygen pulse, respiratory exchange ratio, pulmonary ventilation, and ventilatory equivalents for oxygen and carbon dioxide.

Conclusions

These findings suggest that cardiorespiratory functional capacity during exercise in patients with CHF, as well as cardiopulmonary variables at maximal exercise, may be similarly affected by the heart disease in all studied age groups.

Keywords

exercise, congestive heart failure, age

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Cardiopulmonary exercise testing is a non-invasive method to assess aerobic capacity in patients with heart failure, by determining maximal oxygen uptake (VO_2max) and anaerobic threshold[1].

Maximal oxygen uptake (or peak oxygen uptake) values provide relevant information for the prognosis of these patients[2], allowing identification of those who should be prioritized for heart transplantation[3]. These values, therefore, are essential for the appropriate selection of potential heart transplantation candidates.

VO_2max can also be used to classify functional fitness in patients with congestive heart failure (CHF). Franciosa et al[5] divided patients into four groups according to VO_2max values obtained by cardiopulmonary exercise testing on a cycle ergometer, evaluating 44 patients with ages ranging from 39 to 70, mean age 56. Weber et al[6] also classified CHF patients according to maximal oxygen uptake values obtained by treadmill exercise tests, evaluating 62 patients with ages ranging from 19 to 79, mean age 52 years. In these studies, patients' functional classification was performed regardless of age group.

Oxygen uptake at peak exercise and at anaerobic threshold decline with age[7].

Inbar et al[8] compared cardiopulmonary responses obtained during exercise for 1,424 healthy male subjects age 20 to 70, finding, in addition to a decrease in maximal oxygen uptake and oxygen uptake at the anaerobic threshold, a decrease in maximal carbon dioxide production, heart rate, oxygen pulse, and pulmonary ventilation, plus a slight increase in maximal ventilatory equivalents for oxygen and carbon dioxide. They found no difference in maximal respiratory exchange ratio.

Cardiopulmonary exercise testing can also be used to determine whether exertional dyspnea is caused by a cardiac or a ventilatory problem[7,9-11]. Nery et al[9] compared cardiovascular and respiratory responses to exercise in patients with chronic obstructive pulmonary disease (COPD), mean age 57 years (43 to 63), and mitral valve disease, mean age 33.7 years (20 to 43). Cesar et al[10] compared patients with COPD, mean age 65.5 years (36 to 77) and CHF, mean age 44.4 years (29 to 67). Therefore, these studies failed to compare patients belonging to the same age group.

Although variables measured by cardiopulmonary exercise testing in CHF patients are used for functional classification, such as criterion for heart transplantation, assessment of rehabilitation programs effects and determination of exertional dyspnea etiology[7], studies evaluating these variable results in tests of patients of different age groups are lacking. This paper, therefore, aims at comparing indices of functional cardiorespiratory limitation, maximal oxygen uptake, and anaerobic threshold in different age groups, and also cardiopulmonary responses to maximal exercise in CHF patients.

Methods

Fifty-four CHF patients - class I to IV according to the New York Heart Association - using angiotensin-converting enzyme (ACE) inhibitor, diuretics, digitalis, beta-blockers, amiodarone and/or nitrate in optimal dosages were evaluated. Patients were stratified by age group.

Group I was composed of twelve patients, ages ranging from 30 to 39, mean age 35.2 (SD=2.9), nine male subjects and three female subjects, mean ejection fraction of 25.9% (SD=9.7). From the etiological point of view, seven patients were classified as having idiopathic cardiomyopathy, four as having chagasic cardiomyopathy, and one as having ischemic cardiomyopathy. Two patients were hypertensive, and one, diabetic. Ten patients were in sinus rhythm and two had a cardiac pacemaker. Regarding medications, eleven patients were using ACE inhibitors; eleven, loop diuretics; eight, aldosterone inhibitors; three, thiazide diuretics; eleven, digitalis; three, beta-blockers; three, amiodarone; one, nitrate; two, anticoagulants; and one, oral hypoglycemics.

Group II was composed of eighteen patients, ages ranging from 40 to 49, mean age 46.2 (SD=2.7), fourteen male subjects and four female subjects, mean ejection fraction of 23.9% (SD=9.9), eleven of whom were classified as having chagasic cardiomyopathy, four as having idiopathic cardiomyopathy, and three as having ischemic cardiomyopathy. Four patients were hypertensive. Fourteen patients were in sinus rhythm, two in atrial fibrillation, and two had a cardiac pacemaker. Seventeen patients were using ACE inhibitors; seventeen, loop diuretics; thirteen, aldosterone inhibitors; four, thiazide diuretics; twelve, digitalis; five, beta-blockers; eleven, amiodarone, three, nitrate; four, anticoagulants; and two, antiplatelets.

Group III consisted of seventeen patients, ages ranging from 50 to 59, mean age 54.1 (SD=3.0), thirteen male subjects and four female subjects, mean ejection fraction of 25.1% (SD=7.2), seven of whom were classified as having ischemic cardiomyopathy, five as having idiopathic cardiomyopathy, and five as having chagasic cardiomyopathy. Three patients were hypertensive, and four, diabetics. Fourteen patients were in sinus rhythm, two in atrial fibrillation, and one had a cardiac pacemaker. Regarding medication, seventeen patients were using ACE inhibitors; fifteen, loop diuretics; thirteen, aldosterone inhibitors; four, thiazide diuretics; fifteen, digitalis; six, beta-blockers; five, amiodarone; two, nitrate; three, anticoagulants; four, antiplatelets; three, oral hypoglycemics; and two, insulin.

Group IV comprised seven patients, age 60 and above (60 to 74) mean age 67.0 (SD=4.2), six male subjects and one female subject, mean ejection fraction of 27.6% (SD=13.3), five of whom were classified as having idiopathic cardiomyopathy and two as having ischemic cardiomyopathy. Four patients were hypertensive, and one, diabetic. All seven patients were in sinus rhythm.

Also, all seven were using ACE inhibitors; six, loop diuretics; five, aldosterone inhibitors; three, digitalis; three, beta-blockers; three, amiodarone; three, nitrate; and five, antiplatelets.

This study was approved by the Institutional Research Ethics Committee of the University. After reading a letter informing about the study, all patients signed an informed consent.

The four groups of cardiac patients underwent maximal cardiopulmonary exercise testing on a treadmill Model 2000, Sensor Medics - USA, following the protocol proposed by Weber et al[11,12]. The criterion used to determine maximal exercise was that an increase in workload did not lead to an oxygen uptake exceeding 150 ml/min, attaining a plateau, so that VO_2max was reached[13].

Cardiopulmonary variables were determined during a three-minute rest, throughout the exercise and up to the third minute of recovery. The patient breathed room air, and the expired air was analyzed by a Cardiopulmonary Exercise Testing Instrument (SensorMedics Vmax 29C – USA), which measured and analyzed the airflow and oxygen and carbon dioxide fractions breath-by-breath, calculating oxygen uptake, carbon dioxide production, and pulmonary ventilation.

Functional cardiorespiratory limitation indices during exercise, maximal oxygen uptake (VO_2 max) and anaerobic threshold (AT)[7] by gas exchange were determined, expressed as milliliters per kilogram of body weight (ml/kg/min). The following cardiopulmonary variables during maximal exercise were also determined: oxygen uptake (VO_2max l/min) and carbon dioxide production (VCO_2max l/min), respiratory exchange ratio (Rmax), heart rate (HRmax), oxygen pulse (O_2 pulse max), pulmonary ventilation ($V_E$max), ventilatory equivalents for oxygen ($V_EO_2$max) and for carbon dioxide ($V_ECO_2$max).

Descriptive measures for the variables studied were calculated. To compare the four age groups in terms of anthropometric and cardiopulmonary variables, a single-factor analysis of variance was performed[14].

Results

Body weight, height and body mass index for the four age groups were similar (Table I).

No significant difference was found regarding functional cardiorespiratory limitation indices during exercise, maximal oxygen uptake (VO_2max) and anaerobic threshold (AT), expressed in milliliters per kilogram of body weight, among the different groups of these patients (Table II).

No significant differences were found among the following variables: VO_2max l/min, VCO_2max l/min, HRmax, and O_2 pulse max among the different age groups (Table III).

No significant differences were found also among the following variables: $V_E$max, $V_EO_2$max, $V_ECO_2$max, and Rmax among the groups of CHF patients (Table IV).

Discussion

Maximal oxygen uptake and anaerobic threshold are important indices for CHF investigation and classification[15]. In a study performed with healthy subjects, Barros Neto *et al*[16], demonstrated that these indices decline with age, in men and women alike, sedentary or not. Therefore, we believe that in evaluating cardiorespiratory functional capacity of healthy subjects, not only gender and training

Table I – Descriptive measures and analysis of variance results for body weight, height and body mass index (BMI) for groups I (30 to 39 years), II (40 to 49 years), III (50 to 59 years) and IV (≥ 60 years) of patients with congestive heart failure

	Body weight (kg)		Height (cm)		BMI (kg/m²)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Group I (n = 12)	64.1	16.1	165.2	9.2	23.4	5.0
Group II (n = 18)	67.8	14.6	165.5	10.1	24.7	4.6
Group III (n = 17)	67.8	12.8	163.4	9.0	25.2	3.1
Group IV (n = 7)	73.4	13.6	163.8	5.4	27.2	3.8
	p = 0.601		p = 0.895		p = 0.288	

Table II – Descriptive measures and analysis of variance results for maximal oxygen uptake (VO2max) and anaerobic threshold (AT) for groups I (30 to 39 years), II (40 to 49 years), III (50 to 59 years), and IV (≥ 60 years) of patients with congestive heart failure

	VO_2máx (ml/kg/min)				AT (ml/kg/min)			
	Mean	Standard deviation	Minimum value	Maximum value	Mean	Standard deviation	Minimum value	Maximum value
Group I (n = 12)	19.9	4.8	10.9	29.6	14.7	3.2	7.6	19.6
Group II (n = 18)	18.5	5.0	10.7	29.1	13.2	3.3	9.1	20.7
Group III (n = 17)	17.9	4.3	8.6	27.2	13.7	3.7	7.4	22.2
Group IV (n = 7)	16.9	5.8	9.7	23.9	12.5	4.0	7.1	16.9
	p = 0.580				p = 0.538			

level should be considered, but also age.

In this sample, however, the aerobic capacity of cardiac patients did not seem to be significantly affected by age, because, although mean VO_2max and AT are numerically higher in the younger group, no significant differences were found among the groups, which might be explained by the great individual variation of each group. Indeed, in group I (30 to 39 years), the lowest VO_2max and AT values were 10.9 ml/kg/min and 7.6 ml/kg/min, respectively, whereas in group IV (≥ 60 years), the highest VO_2max and AT values were 23.9 ml/kg/min and 16.9 ml/kg/min, respectively. Besides, VO_2max and AT values in all groups were lower than those expected for the age in sedentary subjects[16]. These findings suggest that, in patients with heart failure, the main limiting factor for aerobic power is associated with intrinsic conditions of the heart disease itself, in all studied age groups.

We recognize that the small number of patients in each group is a limitation in this study. This is due to the fact that all tests included in the study were maximal, once those tests terminated by clinical criteria before the patient reached VO_2max were excluded. Group IV comprised only seven patients, because most of them were candidates for cardiac transplant, and younger cardiac patients were given priority for this procedure. However, in spite of the number of patients, no significant differences regarding cardiopulmonary variables were observed, through variance analysis, among the age groups.

We also recognize the lack of a healthy control group, stratified by age bracket, as another limitation of the study.

The different etiology of heart disease might not have affected the results of this study, since Yazbek Jr et al[17] demonstrated that variables obtained by cardiopulmonary exercise testing do not differ among patients with ischemic, chagasic and idiopathic cardiomyopathy.

Maximal oxygen uptake[8,16,18-21] and maximal carbon dioxide production[8] decline with age in normal subjects. In our study, we found no differences in VO_2max (l/min) and VCO_2max (l/min) in cardiac patients of different ages, suggesting that heart disease may affect these variables regardless of age group. No significant differences are expected in maximal respiratory exchange ratio in subjects of different age group[8,21], and the same behavior was found for Rmax in cardiac patients, showing that VO_2max reduction is proportional to that of VCO_2max in these patients.

Maximal heart rate[8,18-21] and maximal oxygen pulse[8,20,21] decline with age in healthy subjects. Weber et al[6] found lower differences for O_2 pulse max in more functionally compromised cardiac patients. Therefore, the lack of difference in maximal oxygen pulse among CHF groups seems to indicate that functional capacity of cardiac patients may be similarly affected in all studied age group. Nevertheless, maximal heart rate is one of the variables most affected by age, and we found no difference concerning this variable among the study age groups. We attributed this result to those patients who had cardiac pacemakers, were taking beta-blocker or were in atrial fibrillation. Therefore, we cannot definitely say that the similar HRmax in patients of different age groups was a result of the heart disease.

Maximal ventilation during exercise decreases with age in healthy subjects[8,21], due to lower maximal workloads

Table III – Descriptive measures and analysis of variance results for maximal oxygen uptake (VO_2max), carbon dioxide production (VCO_2max), heart rate (HRmax), and oxygen pulse (O_2 pulse max) of groups I (30 to 39 years), II (40 to 49 years), III (50 to 59 years), and IV (≥ 60 years) of patients with congestive heart failure

	VO_2max (l/min)		VCO_2max (l/min)		HRmax (bpm)		O_2 pulse max (ml/bpm)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Group I (n = 12)	1.27	0.40	1.37	0.41	141.2	27.1	9.2	3.1
Group II (n = 18)	1.26	0.40	1.40	0.47	140.6	21.7	9.1	2.9
Group III (n = 17)	1.22	0.40	1.34	0.43	141.2	22.6	8.7	3.0
Group IV (n = 7)	1.25	0.50	1.40	0.54	137.9	23.1	9.1	3.3
	p = 0.984		p = 0.980		p = 0.990		p = 0.979	

Table IV – Descriptive measures and analysis of variance results for maximal pulmonary ventilation (VEmax), ventilatory equivalents for oxygen ($V_EO_2$max) and for carbon dioxide ($V_ECO_2$max), and respiratory exchange ratio (Rmax) for groups I (30 to 39 years), II (40 to 49 years), III (50 to 59 years) e IV (≥ 60 years) of patients with congestive heart failure

	$V_E$max (l/min)		$V_EO_2$max		$V_ECO_2$max		Rmax	
	Mean	St deviation	Mean	St deviation	Mean	S deviation	Mean	St deviation
Group I (n = 12)	61.0	22.3	50.5	10.4	45.3	8.5	1.12	0.08
Group II (n = 18)	62.9	16.7	54.2	14.4	47.7	11.2	1.13	0.11
Group III (n = 17)	58.6	16.9	51.1	10.2	45.1	7.7	1.14	0.12
Group IV (n = 7)	59.8	15.7	53.4	15.8	47.2	13.0	1.13	0.07
	p = 0.914		p = 0.836		p = 0.853		p = 0.948	

reached and the less lactic acidosis tolerance by elderly subjects[8]. The similar $V_E$max found in all groups also seems to suggest a functional cardiorespiratory limitation associated with the heart disease in all age groups. In healthy subjects, a slight increase in $V_EO_2$max and $V_ECO_2$max is expected with age, but in the cardiac patients studied these variables seem not to change with age group.

Concluding, the results suggest that cardiorespiratory functional capacity during exercise in CHF patients, as well as cardiopulmonary variables obtained during maximal exercise, may be similarly affected by the heart disease in all studied age group.

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