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CARDIOPULMONARY EXERCISE TEST WITH RAMP PROTOCOL IN ADULTS WITH HEART FAILURE

ORIGINAL ARTICLE

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ABSTRACT

Introduction and objective: The exercise test with ramp protocol is described as the one which best adapts to physical condition of subjects with heart failure (HF). However, velocity and inclination standard increments have not been described yet. This study aimed to describe the results found after application of an exercise test with ramp protocol adjusted for subjects with HF, New York Heart Association (NYHA) class II and III. Methods: 41 subjects with mean age 46.37 ± 8.98 years and ejection fraction of 31.51 ± 9.45% performed the exercise test with expired gas analysis on treadmill with ramp protocol developed from criteria defined in a study by Barbosa and Silva et al. Statistical Analysis: descriptive analysis was performed with frequency distribution and the test time was presented as mean ± standard deviation. Linear regression model was used and NYHA class, age and ejection fraction were included as explanation variables for the test time. A p value of < 0.05 was considered statistically significant. Results: Mean test time was 8.89 ± 3.57 minutes and the R was 1.12 ± 0.11. Sixty-one percent of the sample presented test duration between 6 and 12 minutes - mean ± 1 standard deviation interval - and 73.2% presented duration between 6 and 15 minutes. Conclusion: This study demonstrated that the majority of the subjects with HF concluded the test with ramp protocol adjusted in time considered adequate in the literature.

Keywords: treadmill test, oxygen consumption, physical endurance.

INTRODUCTION

Heart failure (HF) is a limiting health condition responsible for approximately two million cases in Brazil[1]. The compromising of the heart function associated to the skeletal muscular alterations as well as to the reduction of capillary density contribute to the intolerance to exercise and reduction of functional capacity in this population[2], evidenced by approximate reduction of 50% in oxygen uptake peak (VO_2peak), if compared with healthy individuals[2,3].

The cardiopulmonary exertion test with expired gas analysis is an efficient way of evaluating functional capacity of individuals with HF which permits that the cause to intolerance to exertion is established, the exercise intensity is prescribed in an individualized and safe manner, heart transplant is indicated, as well as prognostic is evaluated[4-14]. Many test parameters are used in the HF evaluation, such as VO_2peak, carbon dioxide production (VCO_2), anaerobic threshold (AT), ventilation-minute (VE), carbon dioxide ventilatory equivalent (VE/VCO_2), oxygen ventilatory equivalent (VE/VO_2) and respiratory exchange ratio (R)[2-5,7,14].

Many protocols of exertion test are used in HF evaluation[3,5,7,8]. The protocols are different in their majority concerning load increment volume, duration of each stage and total exercise time[7]. In the individuals with HF, the exertion test may be early interrupted due to their low tolerance to exertion and to the dyspnea and fatigue symptoms[2,3,7]. Thus, the ramp protocol is described as a conservative protocol which best adapts to the reduced physical condition of this population[2,7]. It is already described in the literature that the increments for performance of test with ramp protocol in cycle ergometer should vary between 10 and 15 watts per minute[7]. However, there is no described standardization about velocity increment and inclination on treadmill for each age group and sex. The most consistent recommendation establishes that the increments should not be higher than a metabolic equivalent[7,15]. Thus, the aim

of this study was to describe the results found from the application of a cardiopulmonary exertion test with ramp protocol adapted for individuals with HF, classes II and III of the NYHA.

METHODS

Subjects

The study was approved by the Ethics in Research Committee of the Institution (legal opinion ETIC 489/06 – Ad 01/07) and all volunteers signed a Free and Clarified Consent Form. Individuals with HF, stage C[16,17], classes II and III of the NYHA were included, regardless of their sex and ethnic group, who did not practice regular physical activity, were aged between 25 and 59 years, presented clinical stability for at least two months, ejection fraction of the left ventricle (EFLV) at rest ≤ 45% and who did not present orthopedic or neurological dysfunction which limit walking performance, pulmonary disease history, unstable angina, uncontrolled arrhythmia or peripheral obstructive arterial disease.

Experimental protocol

The cardiopulmonary exertion test with expired gas analysis (CPX Ultima®, Medical Graphics, the USA) and electrocardiographic record was performed on ergometric treadmill with ramp protocol developed from criteria suggested by the study by Barbosa and Silva and Sobral for healthy individuals[18]. In that study, a table with minimum and maximum velocity and inclination to be reached in the exertion test for each age decade and sex was proposed, so that the test had duration of approximately 10 minutes. In an attempt to adapt the protocol for individuals with HF, polynomial extrapolation of fourth order was initially performed and the reference values for each specific age and sex were determined. On a second moment a pilot study was conducted with five individuals with HF for initial evaluation of the protocol. Since in the pilot study the test was interrupted before six minutes, and in order to also have its duration of approximately 10 minutes in this population, the total velocity and inclination increment was redistributed for duration of 15 minutes, and the velocity and inclination increase at every 10 seconds during the test was recalculated. The increments used as reference for te ramp protocol proposed are described in tables 1 and 2.

The volunteers were told to keep their usual medication, to observe 2-hour fast and avoid food and drink with caffeine, besides smoking and physical exercise on the day of the test[19]. The exertion test was preceded by three minutes of rest with the individual in orthostatism on the ergometric treadmill (Millenium Classic CI®, Inbramed/Inbrasport, Brazil). Subsequently, a three-minute warm-up was initiated, and was followed by the incremental period with the proposed protocol. The heart rate and oxygen peripheral saturation were continuously recorded as well as the blood pressure at every two minutes and at the end of the test. The test was interrupted in case the individual requested it for fatigue or presented any of the absolute criteria for the test interruption, according to the guidelines of the American College Cardiology/American Heart Association 2002[20]. All tests were performed at room temperature of 20 ± 2ºC and relative air humidity between 50 and 70%[21] and followed by a cardiologist with ergometry and life advanced support degree.

Table 1. Increments used as reference for the ramp protocol for men with HF. Velocity: kilometers/hour; Inclination: degrees; Velocity increment: kilometers/hour; Inclination increment: degrees.

Age	Minimum velocity*	Maximum velocity*	Velocity increment†	Minimum inclination*	Maximum inclination*	Inclination increment‡
25	3.6	7.9	0.047	6.0	15.9	0.110
26	3.6	7.9	0.047	6.0	15.9	0.110
27	3.6	7.8	0.047	6.0	15.9	0.110
28	3.6	7.8	0.047	6.0	15.9	0.110
29	3.6	7.7	0.046	6.0	16.0	0.110
30	3.5	7.7	0.046	6.0	16.0	0.111
31	3.5	7.6	0.046	6.0	16.0	0.111
32	3.5	7.6	0.045	6.0	16.1	0.112
33	3.5	7.6	0.045	6.0	16.1	0.112
34	3.5	7.5	0.045	6.0	16.1	0.113
35	3.5	7.5	0.045	6.0	16.1	0.113
36	3.4	7.4	0.044	5.9	16.2	0.114
37	3.4	7.4	0.044	5.9	16.2	0.114
38	3.4	7.3	0.044	5.8	16.2	0.115
39	3.4	7.3	0.043	5.8	16.2	0.115
40	3.3	7.2	0.043	5.7	16.2	0.116
41	3.3	7.2	0.043	5.7	16.2	0.116
42	3.3	7.1	0.043	5.6	16.1	0.117
43	3.3	7.1	0.042	5.5	16.1	0.118
44	3.2	7.0	0.042	5.5	16.1	0.118
45	3.2	7.0	0.042	5.4	16.0	0.119
46	3.2	6.9	0.042	5.3	16.0	0.119
47	3.2	6.9	0.041	5.2	15.9	0.120
48	3.1	6.8	0.041	5.1	15.9	0.120
49	3.1	6.8	0.041	4.9	15.8	0.120
50	3.1	6.7	0.040	4.8	15.7	0.121
51	3.1	6.7	0.040	4.7	15.6	0.121
52	3.0	6.6	0.040	4.6	15.5	0.121
53	3.0	6.5	0.039	4.4	15.4	0.122
54	3.0	6.5	0.039	4.3	15.2	0.122
55	2.9	6.4	0.039	4.1	15.1	0.122
56	2.9	6.4	0.038	4.0	14.9	0.122
57	2.9	6.3	0.038	3.8	14.8	0.122
58	2.8	6.2	0.038	3.6	14.6	0.122
59	2.8	6.2	0.037	3.4	14.4	0.122

* Result of the polynomial extrapolation of fourth order from the study by Barbosa and Silva and Sobral18. † velocity increment in kilometers/hour = (maximum velocity – minimum velocity)/15 minutes x 1/60 minutes x 10. ‡ inclination increment in degrees = (maximum inclination – minimum inclination)/15 minutes x 1/60 minutes x 10.

STATISTICAL ANALYSIS

Data descriptive analysis was performed with frequency distribution considering the entire sample and later the classes II and III of NYHA. Shapiro-Wilk test was performed to evaluate the data distribution. The test time was presented as mean ± standard for the entire sample and separately for each functional class. The multivariate analysis was performed through the linear regression model including the class of the NYHA, age and ejection fraction as explanatory variables for the test time. A $p < 0.05$ was considered significant. The SPSS® software (SPSS Inc, the USA) version 13.0 was used for the analyses.

RESULTS

43 individuals were selected for the study, and, out of these, two were excluded: one for presenting ventricular tachycardia and the other, supraventricular tachycardia, during the warm-up phase which preceded the test protocol. Therefore, 41 individuals (31 men and 10 women; 20 in class II and 21 in class III of NYHA) with age

Table 2. Increments used as reference for the ramp protocol for women with HF. Velocity: kilometers/hour; Inclination: degrees; Velocity increment: kilometers/hour; Inclination increment: degrees.

Age	Minimum velocity*	Maximum velocity*	Velocity increment†	Minimum inclination*	Maximum inclination*	Inclination increment‡
25	3.3	6.8	0.039	5.6	14.9	0.103
26	3.3	6.8	0.039	5.6	14.9	0.103
27	3.3	6.7	0.039	5.6	14.9	0.103
28	3.3	6.7	0.038	5.6	14.9	0.103
29	3.2	6.7	0.038	5.6	14.9	0.103
30	3.2	6.6	0.038	5.6	14.9	0.103
31	3.2	6.6	0.037	5.6	14.9	0.103
32	3.2	6.5	0.037	5.6	14.9	0.103
33	3.2	6.5	0.037	5.6	14.8	0.103
34	3.2	6.4	0.036	5.5	14.8	0.103
35	3.1	6.4	0.036	5.5	14.8	0.103
36	3.1	6.4	0.036	5.4	14.7	0.103
37	3.1	6.3	0.036	5.4	14.7	0.104
38	3.1	6.3	0.035	5.3	14.7	0.104
39	3.1	6.2	0.035	5.3	14.6	0.104
40	3.0	6.2	0.035	5.2	14.5	0.104
41	3.0	6.1	0.035	5.1	14.5	0.104
42	3.0	6.1	0.034	5.0	14.4	0.104
43	3.0	6.0	0.034	5.0	14.3	0.104
44	2.9	6.0	0.034	4.9	14.3	0.104
45	2.9	5.9	0.034	4.8	14.2	0.104
46	2.9	5.9	0.033	4.7	14.1	0.104
47	2.9	5.9	0.033	4.5	14.0	0.105
48	2.8	5.8	0.033	4.4	13.9	0.105
49	2.8	5.8	0.033	4.3	13.7	0.105
50	2.8	5.7	0.033	4.2	13.6	0.105
51	2.8	5.7	0.032	4.0	13.5	0.105
52	2.7	5.6	0.032	3.9	13.3	0.105
53	2.7	5.6	0.032	3.7	13.2	0.105
54	2.7	5.5	0.032	3.6	13.0	0.105
55	2.6	5.5	0.032	3.4	12.9	0.105
56	2.6	5.4	0.031	3.3	12.7	0.105
57	2.6	5.4	0.031	3.1	12.5	0.105
58	2.5	5.3	0.031	2.9	12.3	0.105
59	2.5	5.3	0.031	2.7	12.1	0.105

* result of the polynomial extrapolation of fourth order from the study by Barbosa and Silva and Sobral18. † Velocity increment in kilometers/hour = (maximum velocity – minimum velocity)/15 minutes x 1/60 minutes x 10. ‡ Inclination increment in degrees = (maximum inclination – minimum inclination)/15 minutes x 1/60 minutes x 10.

mean of 46.37 ± 8.98 years and EFLV of 31.51 ± 9.45%, performed cardiopulmonary exertion test with expired gas analysis with the proposed ramp protocol. The VO_2peak reached was in mean 22.35 ± 6.63mL/kg·min^{-1}.

The mean test time was 8.89 ± 3.57 minutes and the R reached was 1.12 ± 0.11. Sixty-one percent of the sample presented test duration between six and 12 minutes, considering the mean ± one standard deviation interval (table 3). 73.2% out of the total of the sample presented test duration between six and 15 minutes.

Linear regression model was used and evidenced that age and ejection fraction did not contribute to the time variation in the exertion test. The class of the NYHA isolatedly contributed with 16.9% of the variation of the test duration (R^2 = 0.169; p = 0.008).

The individuals of the class II of the NYHA ended the protocol in mean time of 10.37 ± 3.61 minutes with mean R of 1.16 ± 0.11 and 15% performed the test in more than 15 minutes (table 3). The test mean duration in the individuals of the class III of the NYHA was of 7.47 ± 2.97 minutes with mean R of 1.08 ± 0.08. Test end in time shorter than six minutes occurred in 28.6% of this population and one individual performed the protocol in time longer than 12 minutes (table 3).

Table 3. Distribution of the duration frequency, in minutes, of the cardiopulmonary exertion test.

Time (min)	Absolute frequency			Relative frequency		
	Total (41)	Class II (20)	Class III (21)	Total (41)	Class II (20)	Class III (21)
< 6.0	8	2	6	19.5%	10.0%	28.6%
6.0 – 7.9	8	4	4	19.5%	20.0%	19.0%
8.0 – 9.9	8	2	6	19.5%	10.0%	28.6%
10.0 – 11.9	9	5	4	22.0%	25.0%	19.0%
12.0 – 14.9	5	4	1	12.2%	20.0%	4.8%
≥ 15.0	3	3	0	7.3%	15.0%	0%

DISCUSSION

In the present study, the mean duration of the cardiopulmonary exertion test with the ramp protocol proposed, performed in adults with HF classes II and III of the NYHA, non-practitioners of regular physical activity, was of 8.89 ± 3.57 minutes and 73.2% of the sample presented test duration between six and 15 minutes. Such findings indicate that the test performed with the ramp protocol developed presented suitable duration for the cardiopulmonary evaluation in the individuals with HF evaluated as described in the literature[1,3,7,8,15,18,22-24]. The application of the proposed protocol is possible on treadmills which present external command with possibility of concomitant velocity and inclination adjustment.

This study evaluated the percentage of the sample in which the target-duration was successfully reached, going beyond the mean of the results. Considering the absolute values of test duration for each individual, it is necessary to be careful in the application of this protocol, since 25% of the individuals from class II and 28.6% from class III presented the time without the maximum and minimum thresholds described as suitable in the literature. Ten percent of the individuals from class II finished the test in less than six minutes, while 15% finished in more than 15 minutes. In the subjects from class III, 28.6% interrupted the test in less than six minutes.

A study by Myers *et al.*[25] described results of the application of a ramp protocol on treadmill in 200 apparently healthy individuals, individualized from the measurement of the maximum velocity of each participant of the research different from the test application. This way of defining the maximum velocity may be accurate, but it requires repeated visits to the health service office, which could make the HF evaluation unviable in the clinical practice. The present study provides an alternative to adapt velocity and inclination of the ramp protocol to the performance of the cardiopulmonary exertion test in this population.

The regression analysis performed demonstrated that the functional class of the NYHA influenced on the test duration, which was expected. It is already described in the literature that the worse the functional class, the worse the exercise capacity and consequently, the exertion test duration would be shorter[26]. On the other hand, correlation between age and test duration was not observed during the test, indicating that in these individuals with HF the functional

capacity stopped exclusively correlating with age, due to the differentiated impact of the disease. As expected, the ejection fraction was not a variable which contributed to the test duration in the proposed model. It has been demonstrated in the literature that the physical capacity is not directly related to the systolic function which, isolatedly, presents moderate to weak correlations with the capacity to perform exercise[27].

Further studies in individuals of different functional classes of the NYHA are necessary to corroborate the applicability of this ramp protocol.

CONCLUSION

The findings of this study demonstrated that the majority of the individuals with HF ended the cardiopulmonary exertion test with the adapted ramp protocol within the duration considered suitable by the literature. However, it is necessary to carefully generalize these results, considering the sample's characteristics and the inclusion of only individuals from classes II and III of the NYHA.

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