Effects of a Prolonged Exercise Program on Exercise Tolerance in Individuals with History of Acute Coronary Syndrome: A Retrospective Study

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Abstract: *Objective*: To verify the influence of a prolonged physical exercise program on physical fitness and cardiovascular parameters, as evaluated by exercise stress test (EST), in subjects with newly diagnosed acute coronary syndrome.

Methods: The sample included 50 subjects distributed by an experimental group (EG; n = 25) and a control group (CG; n = 25). The EG was subject to a program of regular exercise during 52 weeks. All subjects performed two ESTs: one at the beginning and one at the end of the experimental protocol. The first test was performed 2-3 months after the cardiac event. During the EST fitness parameters (speed and incline of the treadmill and test time), cardiovascular parameters (maximum and resting heart rate, maximum and resting blood pressure, and maximum and resting double product), and metabolic equivalents were recorded.

Results: Compared with the first test, in the second EST showed a significant increase (p <0.05) of the absolute values of metabolic equivalents and physical fitness indicators (testing time and maximum speed and incline of the treadmill) in the EG, with a percentage of variation of these parameters significantly higher than in CG. Despite the better physical performance demonstrated by the EG, there were no significant differences between the two groups with respect to cardiovascular parameters.

Conclusion: In this study, the physical training program improved exercise tolerance in individuals with a history of acute coronary events, without an apparent increased cardiac work.

Keywords: Physical training, exercise stress test, cardiovascular disease, double product.

BACKGROUND

Cardiovascular disease (CVD) remains the most common cause of death in Europe, accounting for over 4 million deaths each year. Coronary heart disease accounts for one third of these deaths. In addition, CVD is a major source of disability and contributes largely to rising health costs [1].

Acute coronary syndrome is characterized by a relative decrease in coronary blood flow. The most common difficulties to myocardial perfusion are atherosclerotic plaques, particularly in situations of higher oxygen consumption [2, 3].

In the presence of acute coronary syndrome, the appropriate medical and/or surgical treatment should be accompanied by the prescription of exercise programs. The latter seem to have a crucial role both in primary and in secondary prevention [4].

Cardiac rehabilitation (RC) programs were developed for individuals affected by acute cardiac pathology. These programs are usually divided into 4 phases: the in-patient period is considered phase I; the 12-week convalescence period after hospital discharge, phase II; the extended supervised outpatient program with 4 to 6 months' duration, phase III; and the maintenance period, phase IV (5). RC programs involve medical evaluation, exercise, cardiac risk factor modification, education and counseling for patients [2, 6, 7]. Its objectives are to improve the effectiveness of exercise response and to potentiate cardiovascular and respiratory adaptations to exercise [5-8]. Furthermore, recent studies suggest that exercise may also increase the number and differentiation of endothelial precursor cells, thus allowing a more effective endothelial regeneration and improved myocardial perfusion [8-10].

Given the patients' advanced age and previous heart disease, inappropriate exercise intensity involves some risks [4].

Considering these limitations, the present study aims to verify, in a controlled manner, the influence of a prolonged program of physical exercise on physical fitness and cardiovascular parameters, evaluated during an exercise stress test (EST), in subjects with a recent history of acute coronary syndrome.

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METHODS

The present case-control, retrospective and longitudinal study used a sample selected from a target population of subjects with a diagnosis of acute coronary syndrome, residing in Oporto and undergoing outpatient treatment at one public hospital or one private clinic in Oporto.

The sample consisted of 50 male volunteers divided into an experimental group (EG) (n = 25) and a control group (CG) (n = 25). All subjects were submitted to two EST. The first test was performed 1 to 2 months after the acute coronary event (initial moment - M0), and the second test one year after M0 (final moment - M1).

Exclusion criteria were: i) neurological, musculoskeletal and severe respiratory disorders, heart failure, and recurrence of myocardial infarction, ii) having undergone EST within 3 months of coronary heart disease diagnosis [11] iii) EST interrupted by musculoskeletal pain or electrocardiographic changes iv) change of medication during the experimental protocol.

Exercise Stress Test

Exercise stress test was conducted according to the Bruce protocol on a Schiller CS 100 treadmill Delmar E17. It was initiated with a speed of 2.7 km/h and a 10% gradient incline for 3 minutes. Workload (speed and inclination) was subsequently increased at 3-minute intervals until volitional exhaustion was reached [12].

Training Protocol

The EG underwent a cardiac rehabilitation program according to Lavie (1997) [13], from phase III training to phase IV maintenance [5] for 52 weeks [13]. Each session lasted approximately60 minutes, three times per week [4, 11].

The exercise sessions consisted of approximately 10 minutes of warm-up, 40 minutes of continuous aerobic work and 10 minutes of cool-down [6, 7]. The intensity of the endurance exercise was prescribed individually to achieve 60% to 80% of the maximum HR determined during the first EST (M0), adjusted for each day of training according to the Borg scale (CR10) [4, 5, 7, 11, 14, 15]. This scale has been used mainly for the subjective assessment of pain and/ or dyspnea, but it also seems to be useful for the evaluation of exertion [16].

To better control the risk inherent to physical exercise in the EG, subjects were monitored by telemetry during exercise sessions.

Over the 52 weeks, exercise prescription was periodically adjusted in order to encourage a gradual increase in performance.

Control Group

Control group was not targeted by experts for any exercise program, followed in the hospital cardiology who have not had access to cardiac rehabilitation. The subjects in the CG were selected by pairing EG subjects taking into account age, underlying disease, risk factors for cardiovascular disease, medication, and body mass index.

Outcome Measures

Information on anthropometric measures, medication and risk factors for cardiovascular disease was collected from participants' clinical records.

Weight was measured using a scale (Jofre; 0,1Kg) and height was measured using a standardized tape measure (1mm) mounted on the wall. Body mass index was calculated from these measurements.

The maximum speed and incline of the treadmill, as well as the total trial time were measured digitally, immediately after each EST.

The resting heart rate (HR) was measured with the subject in the seated position, using an electrocardiograph (Shiller; 10 outputs; 12 leads). During EST the HR was monitored using the same electrocardiograph which, in addition, allowed for the qualitative assessment of electrical waves. The maximum HR achieved during exercise was recorded.

Systolic and diastolic blood pressure were measured at rest, before the EST, with a mercury sphygmomanometer (Erka), in seated position. The average of two measurements was recorded [17]. Maximum systolic and diastolic blood pressure were measured in the same way, but with the subject in standing position during the EST. Blood pressure was measured every 3 minutes and the highest value was recorded.

Maximum and resting double product (DP) were calculated as the product of HR by systolic blood pressure (SBP). This was used as an estimate of cardiac work [6, 7, 18].

Metabolic equivalents (METs) achieved during EST allowed for accurate comparison of individual performances using the maximum oxygen consumption [7].

Ethics

This study was submitted to and authorized by the Ethics Committee of the hospital. Participants expressed their consent by signing the Declaration of Helsinki. Anonymity and data confidentiality were maintained throughout the investigation. The CG was given the opportunity to enter the exercise program at the end of the study.

Statistical Analysis

PASW Statistics 18 software (for Windows 7®) was used, with a confidence interval of 95% and a significance level of 0.05.

The sample distribution was normal, using the Kolmogorov-Smirnov test. For the descriptive analysis mean values, standard deviations and frequencies were used.

For comparison between the experimental and control groups, the t test for independent samples was used. To compare the intragroup variations, considering the two time points, the t test for paired samples was used. Finally, cross-sectional analysis was performed between groups using the percentage of variation of the results from M0 to M1 and the t test for independent measures. The chi square test was used to compare the relative frequencies of risk factors in the two groups.

RESULTS

Anthropometric characteristics, risk factors for cardiovascular disease and medication at M0 are shown in Table **1**. These variables showed no significant differences between M0 and M1, intra or intergroup ($p>0.05$).

As for underlying pathology, the majority of subjects in each group (88%) were diagnosed with acute myocardial infarction while the remainder (12%) were diagnosed with angina pectoris. In the acute setting patients were subjected to percutaneous transluminal

Table 1: Anthropometric Characteristics of the Sample, Risk Factors for Coronary Heart Disease and Drug Therapy Instituted Immediately Prior to the First Exercise Stress Test, in Experimental and Control Groups

	Control Group	Experimental Group
Anthropometric characteristics	Mean ± standard deviation	
Age (years)	56,9±10,2	57,6±9,2
Weight (Kg)	77,4±9,6	73,4±9,1
Height (cm)	169,2±9,2	168±5,7
BMI (Kg/m^2)	27,0±2,9	26,0±2,7
Risk Factors for Coronary Heart Disease	Relative frequency (%)	
Dyslipidaemia	76	64
Diabetes	20	12
Family history	16	16
Tobacco	40	52
Obesity	12	12
Stress	20	16
Hypertension	36	32
Pharmacological Therapy	Relative frequency (%)	
β-blockers	88	92
Nitrates	12	20
Statins	76	64
Anti-aggregatory	28	20
Isosorbidemononitrate	12	20
Angiotensin-converting enzyme inhibitors	36	16

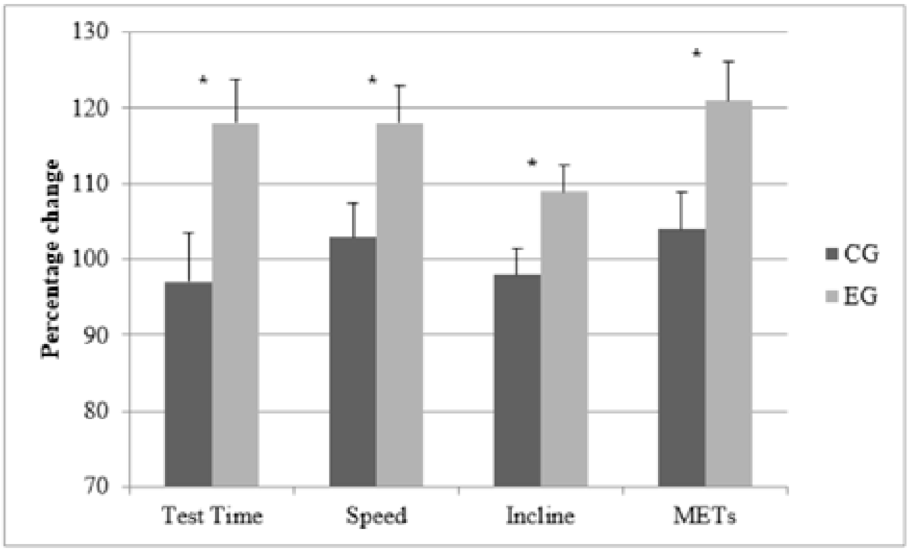

Figure 1: Graphical representation of means and standard deviations of the percentage change of the parameters of physical fitness (test time, and speed and incline of the treadmill), and metabolic equivalents (METs) in the experimental (EG) and control (CG) groups. * p<0,05 *vs*. CG.

coronary angioplasty (52% in each group), pharmacologicaltreatment (22% in each group) or coronary bypass surgery (26% in each group).

In the comparative analysis of the two groups atM0, there were no significant differences in any dependent variables.

The average testing time increased significantly from the first (8.9±2.3minutes) to the second test (10±1.7minutes) in the EG (p≤0.05), while in the CG it was no differences were found between the first (9.7±2.6minutes) and the second test (9.1±2.3minutes) (p>0.05). The maximum speed and incline of the treadmill during the EST significantly increased in the EC when comparing the first and second test, respectively 5.4±1.2km/h to 6.3±1km/h and 14.6±1.3% to 15.8±1% (p≤0.05). In the CG there were no significant variations between the two tests for these parameters (5.9±1.2 km/h to 6.0±1km/h and 14.8±1.6% to 14.5±2.2%)(p>0.05).

Metabolic equivalents increased in both groups during the study. The variation from the first to the second test was 11.6±2.9 to 11.7±2.3 in the CG and 11.0±2.2 to 13.0±1.8 in the EG. This increase in MET averagewas statistically significant in the EG (p≤0.05).

The changes from M0 to M1in both groups regarding test time, maximum speed and incline of the treadmill and METs, are shown in Figure **1**.

Regarding the cardiovascular parameters described in Table **2**, resting systolic and diastolic blood pressure were not significantly different in the two evaluation moments (p>0.05) for the EG. In the CG, the resting diastolic blood pressure (DBP) increased significantly (p≤0.05). The resting HR did not change significantly in either group (p>0.05).

Maximum SBP increased significantly in the EG, while in the CG there were no significant differences (p>0.05). The mean change in maximum HR from M0 to M1 was very small for the CG, with no significant results (p>0.05). In the EG the maximum HR increased significantly (p≤0.05) (Table **2**).

Table 2: Mean Values and Standard Deviations of Blood Pressure and Heart Rate, in the Two Moments, in the Experimental and Control Groups

Variable	Group	M0	M1
Resting SBP (mmHg)	CG	122,8±16,7	129,4±14,6
	EC	121,4±18,1	124,4±13,9
Resting DBP (mmHg)	CG	78±11,6	83±10,9 a)
	EG	72,2±9,5	75±9,4
Maximum SBP (mmHg)	CG	168±21,9	168,8±20,5
	EG	168,2±23,8	169,6±20
Maximum DBP (mmHg)	CG	79±12,4	83±13,1
	EG	74,2±11,2	75,2±10
Resting HR (bpm)	CG	75,04±12,4	75,64±13,9
	EG	73,92±13,5	71,48±10,4
Maximum HR (bpm)	CG	135,6±19,6	133,76±19,3
	EG	134±19,5	143,64±22,8[a]

[a]p≤ 0,05 *vs*. M0.

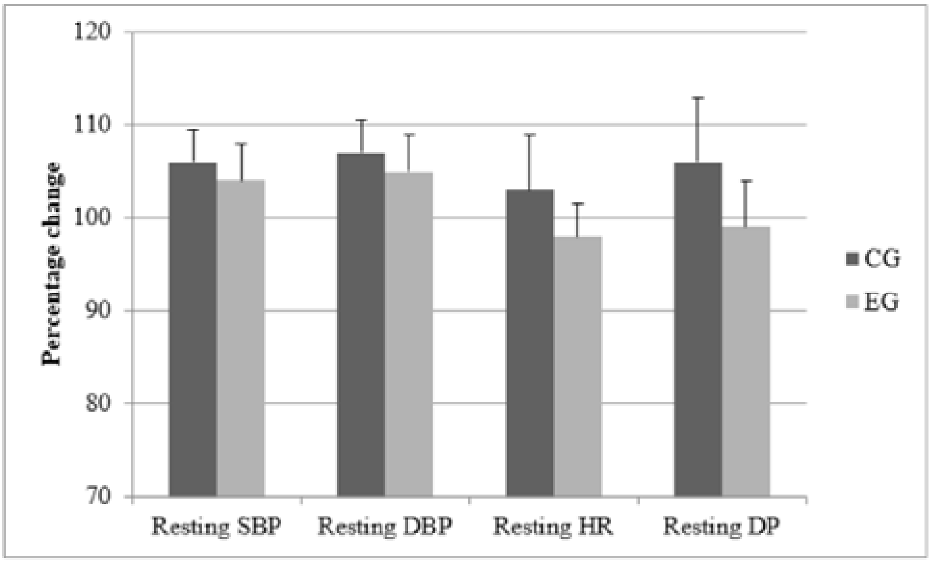

Figure 2: Graphical representation of means and standard deviations of the percentage of cardiovascular parameters evaluated at resting: systolic (SBP) and diastolic (DBP) blood pressure, heart rate (HR) and double product (DP), in experimental (EG) and control (CG) groups.

Resting DP did not vary significantly in either group (p>0.05). In the EG the average ranged from 8960±2060 bpm*mmHg at M0 to 8857±1378 bpm*mmHg at M1, whereas in the CG the average ranged from 9272±2221bpm*mmHg at M0 to 9811±2149bpm*mmHg at M1 (p>0.05). The perceptual change in the second EST as for resting SBP, resting DBP, resting HR and resting DP showed no significant differences between groups (p>0.05) (Figure **2**).

Maximum DP in experimental and control groups did not change between the two EST (EG: 22610±4872 bpm*mmHg at M0, and 23836±4454 bpm*mmHg at M1, p> 0:05; CG: 22850±4846 bpm*mmHg at M0, and 22698±4582 bpm*mmHgatM1, p> 0:05).

The percentage of change in maximum HR, maximum blood pressure and maximum DP are shown in Figure **3**.

DISCUSSION

The results show that subjects who underwent the exercise program for one year increased their exercise tolerance, improving the parameters of fitness without noticeable changes in cardiovascular parameters,

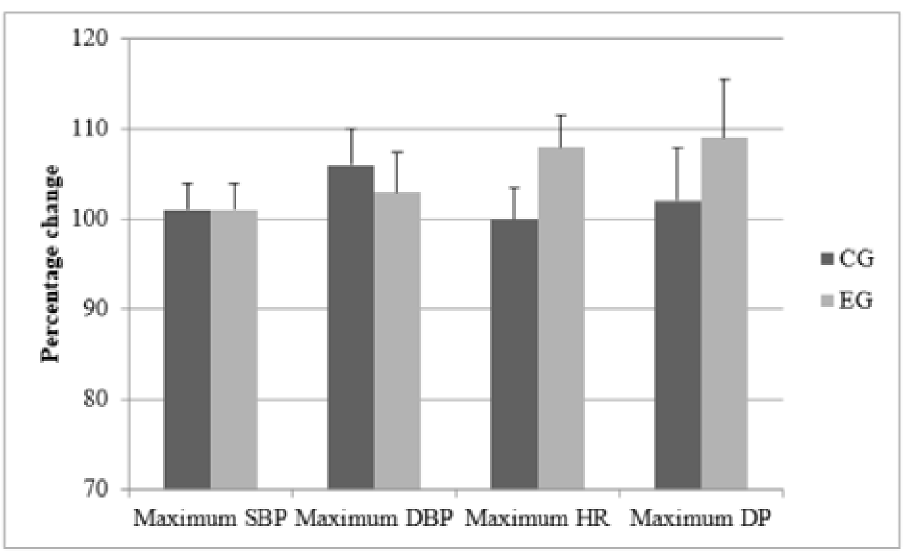

Figure 3: Graphical representation of means and standard deviations of the percentage of cardiovascular parameters evaluated in effort: systolic (SBP) and diastolic (DBP) blood pressure, heart rate (HR), and double product (DP), in experimental (EG) and control (CG) groups.

which suggests an increased efficiency of the cardiovascular function. Even though the CG did not undergo any physical training program, there seems to have been, over 52 weeks, no deterioration in their exercise tolerance or in cardiovascular parameters analyzed, a situation likely explained by the positive effects of the therapy in effect.

The increase in exercise tolerance observed in the EG could be explained by neural adaptations, as well as metabolic and structural adaptations [6, 7, 19]. These neuromuscular adaptations may even have contributed to the increased tolerance to acute exercise, but it should be noted that they do not by themselves justify the apparent absence of additional cardiovascular overload, shown by the absence of change in DP. Furthermore, taking the recent coronary event into consideration, in M0 the main factor in determining cardiovascular maximum effort is speculated to be limited functionality.

Given that maximum effort is highly influence by limits imposed by the cardiovascular system, it is to be expected that the cardiovascular adaptations motivated by physical training and widely described in the literature may have been decisive to justify the increase in exercise tolerance observed for the EG [4, 18]. These adjustments occur at a central and peripheral level, encompassing an increase in cardiac function and an improvement in endothelial function [4, 18]. Cardiovascular adaptations motivated by physical training could be explained by increased circulating endothelial precursor cells, which appear to favor endothelial regeneration after damage as well as neo-vascularization of the ischemic zone, thus allowing better perfusion [8-10]. In basal conditions these chronic adaptations usually lead to a decrease in HR and the normalization of blood pressure (BP) in hypertensive subjects during acute exercise, manifested by an increased ability to carry oxygen to tissues with the consequent increased maximum oxygen consumption [7].

The fact that the exercise program did not modify the resting values of BP and HR in the EG could put into question the existence of cardiovascular adaptations. However, it is important to note that these subjects undertook both ESTs while treated with β-blockers and/ or anti-hypertensives, thus justifying the low values of resting BP and resting HR found, as well as the lack of variation in these parameters between the two ESTs [7]. Even so, it is worth noting that while values of resting DBP in the CG increased significantly from the first to second assessment, in the EG there was no differences between the two moments, suggesting the protective effect of physical training. In fact, considering the sample pairing regarding medication and the exclusion criteria used in this study, the results should be analyzed in terms of physical training and not so much for medication given that this was similar for both groups in both moments.

With respect to the parameters evaluated during acute exercise it should be noted that during skeletal muscle contraction an increase in cardiovascular functionality is required, increasing the cardiac debit and channeling blood flow to the recruited muscles in order to maintain homeostasis [4, 6, 7]. The greater the intensity of the exercise, and consequently the greater the loss in homeostasis, greater will be the demand on the cardiovascular system. This can be evaluated in a simple and straightforward way, albeit coarsely, by changes of HR, BP and DP [20]. Although there have been no changes in maximum BP, the maximum HR increased significantly in the EG in the second test, without electrocardiographic abnormalities. Regardless of the hypothetical influence of medicines, discussed earlier, these results suggest a higher tolerance to cardiac cardiovascular overload in the EG individuals, explained by adaptations induced by the physical training program. Despite this change in maximum HR in the EG there were no changes in maximum DP after one year. However, the EG individuals endured a much larger physical effort, suggesting a higher cardiac efficiency in the EG.

Although there are several studies about the effects of exercise programs on tolerance, in individuals with acute coronary syndrome, only short programs (8-12 weeks) are evaluated. However, this study involves a long-term protocol (52 weeks) of exercise, a much longer intervention than the majority of the studies, supporting the beneficial effects of short programs, which are maintained after phase III. However, data on what defines the optimal duration of an exercise program is scarce and the available evidence is clearly insufficient to support clinical or policy decisions [21]. It seems relevant, as stated in Lawler *et al*. (2011), to compare the effectiveness and cost-effectiveness of short and long term exercise programs on the secondary prevention of cardiovascular events [21].

Some methodological limitations can be identified in this study: the small sample size. However, despite this potential limitation, it is noted that the variables studied showed a normal distribution and homogeneous variance, allowing for statistical confidence in the results. Experimental group individuals may have become more trained in the treadmill, thus making it more familiar on the day of the second EST. However, from the methodological point of view this limitation is not likely to be exceeded. Exercise stress test were always performed by the same professionals, but given the type of evidence filled in makes the variation in the professional performing the exam less relevant.

CONCLUSION

Taking into account the results obtained, it was concluded that the physical training program improved exercise tolerance in individuals with a history of acute coronary events, without an apparent cardiac overload.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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