

Aerobic Physical Training On The Pulmonary Function Of Men With Coronary Arterial Disease: A Randomized Controlled Trial

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Abstract

Objective: to evaluate the pulmonary function of patients with coronary arterial disease (CAD) before and after exercise-based cardiac rehabilitation program with emphasis on aerobic physical training.

Methods: 19 men with CAD, divided in trained group TG (n=10) and control group CG (n=9) were studied. Forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) were carried out at 2 points for both groups: at the beginning and finale of the experimental protocol to evaluate and to compare the CG and TG. The CG participated in the evaluations only and is not subjected to any intervention, and the TG was submitted to 48 supervised aerobic physical training sessions to verify the effects of physical training on pulmonary function.

Results: At the beginning of the study all the patients showed low values for FVC and FEV1 in relation to what was expected (CG: $72.2 \pm 9.1\%$ and $72.4 \pm 16.3\%$, respectively; TG: $77.5 \pm 12.1\%$ and $75.2 \pm 13.6\%$, respectively). After the training period, the CG values did not show any significant changes in comparison to the pre-training conditions for FVC ($76.1 \pm 11.5\%$) and FEV1 ($75.4 \pm 17.2\%$). In the TG there was a significant increase in both FVC ($86.1 \pm 12.1\%$) and FEV1 ($86.0 \pm 15.3\%$).

Conclusion: There was a significant increase in FVC and FEV1 values in the TG patients after four months of participation in exercise-based cardiac rehabilitation program, and this fact suggests beneficial effects of aerobic exercise on the pulmonary function of patients with CAD.

Keywords: Cardiac rehabilitation; Cardiovascular diseases; Pulmonary function tests; Aerobic exercises

Introduction

The existence of a significant relationship between pulmonary function and mortality from cardiac diseases of ischemic origin has been mentioned in the literature [1,2]. The reduction of pulmonary function, evaluated through the forced expiratory volume after one second (FEV1) and forced vital capacity (FVC), is associated with coronary events, and contributes to the increase of mortality from cardiovascular diseases [3-5].

Due to the increase of cardiovascular diseases, non-pharmacological treatment alternatives have been suggested, such as the cardiac rehabilitation (CR) [6]. Meta-analyses show that CR with emphasis on aerobic physical exercise is associated with reduction of mortality rate when compared to the other components of the program [6,7].

Exercises are acknowledged as important tools in CR, as they have low cost and reduce coronary arterial disease (CAD) risk factors, consequently promoting benefits such as physical condition improvement and reduction of both myocardial ischemia [8,9] and cardiac mortality [6,7] aerobic exercises are the most used in cardiopaths' physical training [10,11].

Even though the association between pulmonary function and cardiac diseases is well described [3,5,12], studies that evaluate the adaptations of the pulmonary function in patients with CAD who have been submitted to CR programs are still scarce.

The hypothesis is that the participation in a CR program with emphasis on aerobic physical exercises would be effective in improving the pulmonary function of people with coronary arterial disease. To investigate this hypothesis, we evaluated the pulmonary function of a group of patients with CAD before and after four months of

participation in a supervised aerobic physical training program.

Methods

This was a randomized controlled study. Seventy patients with CAD diagnosis were screened based on the results of angiocoronariography. As exclusion criteria, the following conditions were considered: renal or hepatic impairment, chronic obstructive pulmonary disease, neoplasias, insulin-dependent diabetes, without any signs of infection or with other major diseases. Patients who did not comprehend the protocol and/or disagreed with their participation in the study were also excluded.

The patients were submitted to the clinical treadmill stress test (Inbrasport ATL, Porto Alegre, RS, Brazil). The protocol was carried out by the physician and researchers responsible for the study, aiming to evaluate the patients' clinical responses to the exercise. The abnormalities presented in this test that contraindicated the practice of physical activity were considered as an exclusion criterion for the study.

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The sample size was based on the standard deviation obtained in a pilot study performed by a responsible researcher, in which the spirometry of ten men with CAD. Establishing a significance level of 5% and a test power of 80%, the number of subjects suggested was 13 in each group. For the calculation, the GraphPad StatMate 2.0 for Windows software was used.

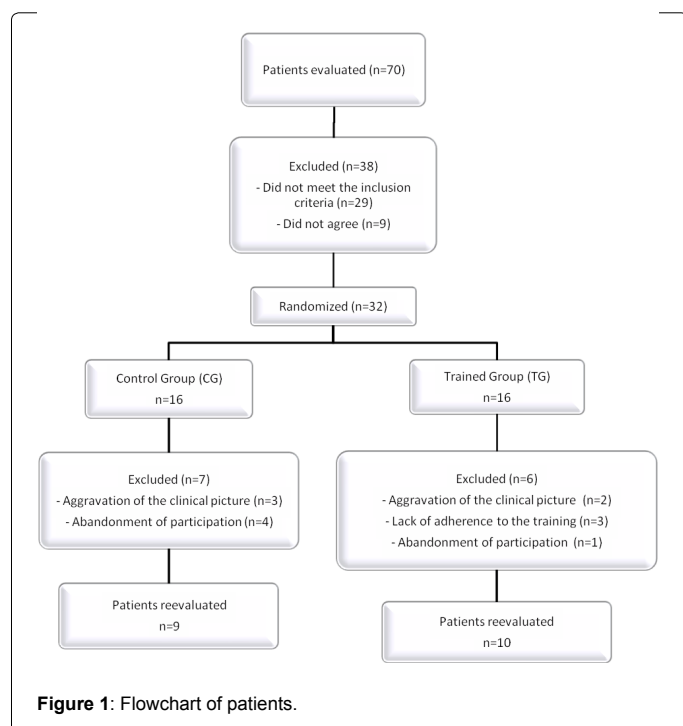
The randomization was carried out by means of a numeric table generated by a randomization software (GraphPad StatMate 2.0 for Windows).

The groups were the control group (CG, n=16) who participated in the evaluations, and the trained group (TG, n=16) who participated in both the evaluations and the cardiac rehabilitation program with emphasis on aerobic physical training, and they were considered as. During the development of the experimental protocol, there was a sample loss of six participants from the TG and seven participants from the CG, due to aggravation of the clinical picture, lack of adherence to the training protocol, and abandonment of participation in the research. Thus, the study was concluded with 10 patients in the TG and nine patients in the CG (Figure 1).

The study was approved by the Research Ethics Committee of the involved institution and by the Research Ethics Committee of the hospital where the experimental procedures were carried out. The subjects signed a free and informed consent form to participate in the study.

Experimental protocol

For carrying out the experimental protocol, four physical therapists participated in the procedures. The first one was responsible for the screening and randomization, the second for taking the spirometric testing, the third for supervised aerobic physical training program, and the fourth for the analysis of results. The physical therapists responsible for the spirometric testing and analysis of results were blinded, i.e., they did not know the group the subjects belonged to.



Spirometric testing

Pulmonary function tests were carried out at 2 points for both groups: at the beginning and finale of the experimental protocol to evaluate and to compare the CG and TG. The CG participated in the evaluations only and is not subjected to any intervention, and the TG was submitted to 48 supervised aerobic physical training sessions to verify the effects of physical training on pulmonary function.

The experiments were carried out in the afternoon (to avoid circadian interference) in a climate-controlled room (21-24°C) with a relative air humidity of 40-60%. All patients were familiarized with the laboratory environment and the experimental protocol.

The pulmonary function tests were carried out with a spirometer (Easy one™, ndd Medizintechnik AG, Zurich, Switzerland) according to American Thoracic Society (ATS) guidelines [13] for technique, acceptability and reproducibility. The device was calibrated before each test according to manufacturer's instructions. Spirometric variables were recorded and expressed in BTPS (body temperature and pressure, saturated) conditions.

The measurement protocol was as follows: first, the subject, after having the procedures carefully described to him, rested for 10 minutes. The exam then began with the subject seated upright (90° hip flexion angle) with his head in neutral position and wearing a nose clip to avoid air leakage through the nostrils. The mouthpiece was correctly placed over subject's mouth to avoid air leakage.

For the FVC maneuver, the subjects were instructed to maximally inspire and then to exhale completely with maximum effort. Participants were verbally encouraged to exhale forcibly until the end of the maneuver. Expiration was interrupted after 6 seconds.

Each maneuver was carried out until three acceptable and two reproducible curves were obtained without exceeding eight attempts. During the maneuvers, real-time graphics of the curves were provided, indicating whether they met the acceptance criteria proposed by the ATS [13].

The tests were superimposed automatically in the equipment, which made it easier to verify their reproducibility. Thus, after the acceptance criteria were fulfilled, the curves were classified according to reproducibility, with the maximal differences for FVC and FEV1 in the two best curves (i.e., less than 5% or 150 mL) being considered for analysis. Tests that exceeded these limits were excluded.

The curves considered technically inappropriate were excluded from the analysis. After the acceptability and reproducibility criteria were met, the highest values of the studied variables were recorded.

The absolute values were obtained based on spirometric tests and the percentage of the predicted value of each group for FVC, FEV1, and FEV1/FVC ratio. Based on the equations for healthy subjects developed by Pereira et al. [14] for use as guidelines in pulmonary function tests, equations were used to predict normal values in order to verify the presence of ventilatory dysfunctions.

Intervention protocol

The supervised aerobic physical training program was based on the results of the cardiopulmonary stress test (CPT) using a system of expelled gases measurements (CPX/D MedGraphics – Breeze, St. Paul, MN, USA), which was carried out on an electromagnetically braked cycle ergometer (model Corival 400, Quinton, Seattle, WA, USA), with patients taking their regular medications.

The physical training protocol of 16 weeks with 1-hour sessions was individualized and supervised, and was composed of three weekly sessions (on alternate days), with a total of 48 sessions. Each session was divided into three phases: 1st phase: 10 min of warm-up, including stretching exercises, calisthenic exercises, walking, and coordination exercises associated with respiratory exercises in a standing position. 2nd phase: physical conditioning carried out on a cycle ergometer and subdivided in 6 phases, based on workload intensities determined from power (Watts), heart rate (HR - bpm) and maximal aerobic capacity (VO₂) (mL.kg⁻¹.min⁻¹) attained at the ventilator anaerobic threshold (VAT) in the CPT [15,16]. Initially, the conditioning lasted for 25 min, and according to the adaptive responses from the subjects this time was adjusted until it reached a total of 40 min.

- a) Phase 1 of conditioning: exercise with 80% of VAT (5 min).
- b) Phases 2 and 4 of conditioning: exercise with 100% of VAT (5 min and progression until 10 min, subdivided into two steps).
- c) Phases 3 and 5 of conditioning: exercise with 110% of VAT (3 min and progression until 5 min, subdivided into two steps).
- d) Phase 6 of conditioning: exercise with 70% of VAT (5 min).

At the end of each session, cool down exercises were done for 10 min so that the blood pressure (BP) and HR attained near basal values.

In order to check the presence of any factor that could contraindicate the performance of the exercises during all the phases of each session, HR and BP values were measured and recorded, as well as signs and/or symptoms were observed.

Statistical Analysis

The Shapiro-Wilk test was employed to verify data distribution, and the sampling presented normality. Thus, for the significance analysis, the t test was used for paired and unpaired samples. The data were expressed as mean and standard deviation, with a significance $\alpha=5\%$.

Besides the t test, the possible influence of training was tested using a measure of the effect (effect size) to compare TG with the CG. For this method was used Cohen's method. This analysis was performed by the application "Size Effect Generator", Version 2.3 (Swinburne University of Technology, Center for Neuropsychology, Melbourne, Australia). The results were interpreted according to the proposed Cohen [17], considered a value below 0.3 as a small effect, between 0.4 and 0.7, medium, and from 0.8 a large effect.

Results

Group characteristics at the beginning of experimental protocol are presented in Table 1. No statistically significant difference was found between the 2 groups with regard to age, body mass, height, body mass index (BMI) and FVC, FEV1, FEV1/FVC obtained from spirometric testing.

In the comparison of results obtained in relative values (%) of the CG, there was not a significant difference when comparing pre- and post-training, for both FVC ($p=0.09$), and FEV1 ($p=0.31$). In the TG, there was a significant increase in FVC ($p=0.01$) and FEV1 ($p=0.006$) values in the post-training condition. The TG post-training values were higher than the CG post-training values (FVC, $p=0.04$ and FEV1, $p=0.04$), with large effect size for both FVC (0.84) and for VEF1 (0.86), whereas in the pre-training condition the values were similar (FVC, $p=0.14$ e FEV1, $p=0.70$) (Table 2).

Discussion

Due to the relationship between coronary jeopardy and pulmonary function, Friedman et al. [1] and Engstrom et al. [3] suggest that the respiratory variables can be used as predictors of coronary events. In the same way, Schroeder et al. [18] analyzed the relationship between pulmonary function and cardiovascular mortality, and observed that the decrease of FEV1 can be an indicator of mortality from cardiac disease. Also, Sin and Man [5] specifically observed that the decrease of FEV1 is an indicator of future morbid and mortality, independently of tobacco smoking.

As shown in Table 1, for all the patients with CAD, FVC and FEV1 presented reduced values in the initial evaluation, based on the equations for healthy subjects developed by Pereira [14] for use as guidelines in pulmonary function tests, equations were used to predict normal values in order to verify the presence of ventilatory dysfunctions. In this context, the results of the present study demonstrate a relationship between the reduction of pulmonary function and CAD. In the investigations by Speizer et al. [19] and Hole et al. [2] the FEV1 index was categorized in quintiles and it was possible to demonstrate that individuals with FEV1 in the lowest quintile (between 75% to 80% of the prediction) had an increment of 75% in cardiovascular mortality risk, when compared to those with FEV1 in the highest quintile. They also observed that even among non-smoking individuals this relationship was present, suggesting that the reduction of pulmonary function independently of tobacco smoking is a significant pointer of cardiovascular mortality.

Aiming to reduce the deleterious effects of the atherosclerotic process on these patients, non-pharmacological treatment alternatives, such as physical activity, are promoted as a therapeutic means [20]. However, what remain at an incipient stage the descriptions regarding the adaptations of the respiratory system to this type of exercise.

Therefore, the results of the present study showed that after four months of supervised aerobic physical training the TG presented a significant increase in FVC and FEV1 values (11.02% and 14.25%,

	CG (n=09)	TG (n=10)
Age (years)	60.7 ± 10.1	56.0 ± 6.4
Height (cm)	171.8 ± 5.2	168.5 ± 7.9
Body mass (kg)	80.0 ± 19.4	77.8 ± 14.8
BMI (kg/m ²)	26.8 ± 5.2	27.2 ± 3.5
Spirometric variables		
FVC (%)	72.2 ± 9.1	77.5 ± 12.1
FEV1 (%)	72.4 ± 16.3	75.2 ± 13.6
FEV1/FVC (%)	98.6 ± 11.4	99.1 ± 9.1

Table 1: Characteristics of the groups studied.

	CG	TG	Effect size		
TG vs. CG					
	Pre	Post	Pre	Post	
FVC (%)	72.2 ± 9.1	76.1 ± 11.5	77.5 ± 12.1	86.1 ± 12.1*†	0.84
FEV1 (%)	75.4 ± 17.2	72.4 ± 16.3	75.2 ± 13.6	86.0 ± 15.3*†	0.86

Abbreviations: FVC: forced vital capacity; FEV1: forced expiratory volume after 1 second.

* $p<0.05$: pre TG vs. post TG; † $p<0.05$: post TG vs. post CG.

Table 2: Percent values of the predicted forced vital capacity (FVC) and forced expiratory volume after 1 second (FEV1) of the control group (CG) and trained group (TG), in pre- and post-training conditions. Values of effect size between TG e CG.

respectively), showing an improvement of pulmonary function which was not observed in the CG, with effect size being considered large [17]. These results corroborate the findings of Kaminsky et al. [21], who evaluated the effect of a cardiac rehabilitation program on the pulmonary function of patients with CAD, and came to the conclusion that there was an improvement of this function. Despite the fact that we dealt with another population, our findings also agree with those described by Zielinska et al. [22], who evaluated the pulmonary function of patients with congestive cardiac failure and observed a positive relationship between physical exercise and pulmonary function.

Considering the existence of a relationship between inflammatory markers and CAD [23], and the reverse relationship between pulmonary function and inflammatory biomarkers such as c-reactive protein (CRP) and fibrinogen [24,25], the possible justification for the increase of pulmonary function after the supervised physical exercises program may be related to the fact that aerobic exercises promote an improvement in endothelial function, with a consequent reduction of the systemic inflammatory process, as several studies that evaluated inflammatory markers and endothelial injury demonstrated a positive effect of physical training on these markers [26,27].

The findings of the present investigation highlight two aspects: the importance of the pulmonary function evaluation in this population, since the literature reports several studies suggesting spirometric variables as predictors of coronary events [3,5,12,19] - and the patients showed a decrease in FVC and FEV1 - and the fact that these patients must be encouraged to do physical exercises, as, besides cardiovascular benefits, aerobic physical exercises promoted positive effects on the pulmonary function.

In conclusion it was possible to observe a significant increase in FVC and FEV1 values after four months of supervised aerobic training, suggesting beneficial effects of aerobic physical training on the pulmonary function of patients with CAD.

Study limitation was not evaluating inflammatory markers, it is possible to rely on the literature and hypothesize that the benefits of physical exercise on the pulmonary function of the patients studied are related to the reduction of the systemic inflammatory process, since studies demonstrate that aerobic physical training promotes the reduction of atherogenic cytokines and the increase of atheroprotective cytokines, which reduces the inflammatory markers associated with endothelial dysfunction [21,27-30].

With respect to screening of subjects, due to number of patients of the groups is low, were not excluded from the study smokers, which could affect the results, however, based on literature studies associating smoking, lung function and systemic inflammation, reported that the reduction in lung function was is linked to coronary atherosclerosis, regardless of smoking [5,19].

Another limitation concerns the number of patients. The sample size calculation, it would be ideal 13 per group. But despite study began with 16 over the course of the experimental protocol there was loss of seven patients in the CG, and six in TG so we could not its completion with a greater number participants.

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Conflicts of Interest

Conflicts of interest have not been reported by the authors or by any individuals in control of the content of this article.

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