

Effects of an Inspiratory Muscle Rehabilitation Program in the Postoperative Period of Cardiac Surgery

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Summary

Background: Respiratory muscles are affected after cardiac surgeries.

Objective: To verify whether the preoperative conditioning of the inspiratory muscles might help to decrease postoperative respiratory dysfunction.

Methods: Thirty volunteers of both genders and with a minimum age of 50 years, while waiting for myocardial revascularization and/or cardiac valve surgery, were randomly assigned to two groups. Fifteen patients were included in a domiciliary program of at least 2 weeks of preoperative training of the inspiratory muscles, using a device with a load corresponding to 40% of the maximum inspiratory pressure. The other 15 patients received general advice and did not train the inspiratory muscle. Spirometry, before and after the training program, as well as the evolution of the arterial blood gases and of the maximum inspiratory and expiratory pressure, before and after the operation were evaluated in both group.. The clinical outcomes of the two groups were also compared.

Results: We observed that inspiratory muscle training increased the forced vital capacity, the maximum voluntary ventilation and the ratio between the forced expired volume during the first second and the forced vital capacity. The evolution of the arterial blood gases and of the maximum inspiratory and expiratory pressures before and after the operation was similar in both groups, with the outcomes also being similar.

Conclusion: We concluded that our domiciliary program of inspiratory muscle training was safe and improved the forced vital capacity and the maximum voluntary ventilation, although the clinical benefits of this program were not clearly demonstrable in the present study. (Arq Bras Cardiol 2009;92(4):261-268)

Key words: Respiratory muscles; thoracic surgery; postoperative care; physical therapy modalities; rehabilitation.

Introduction

Respiratory complications are among the most common causes of morbidity and mortality after cardiac surgery¹⁻³. Respiratory dysfunctions in cardiac postoperative are usually multifactorial and alterations due to cardiopathies⁴, to surgery itself⁵⁻⁷ and to limitations of the pulmonary functional reserve due to aging^{8,9} have a preponderant role. Several studies suggest that although multifactorial, the morbidity and mortality due to pulmonary causes in the postoperative period could be reduced by training the respiratory musculature altered by cardiopathies and aging¹⁰. However, this is a controversial matter and there are only few reports on the role of respiratory muscular training in the prophylaxis of

respiratory complications arising in cardiac postoperative period¹¹⁻¹³.

The aim of this investigation was to evaluate if a preoperative training program for the inspiratory muscles, conducted at home and designed to improve respiratory functions, would contribute to reduce morbidity and/or mortality in adult patients submitted to myocardial revascularization surgery and/or valvuloplasty.

Patients and Methods

Figure 1 shows the timeline of the interventions and data collection.

Patients

The study included 30 voluntary patients of both sexes, without race discrimination, under 50 years of age, who were submitted to myocardial revascularization surgery or valvuloplasty. All patients signed the Free and Informed Consent Form and the investigation was approved by the

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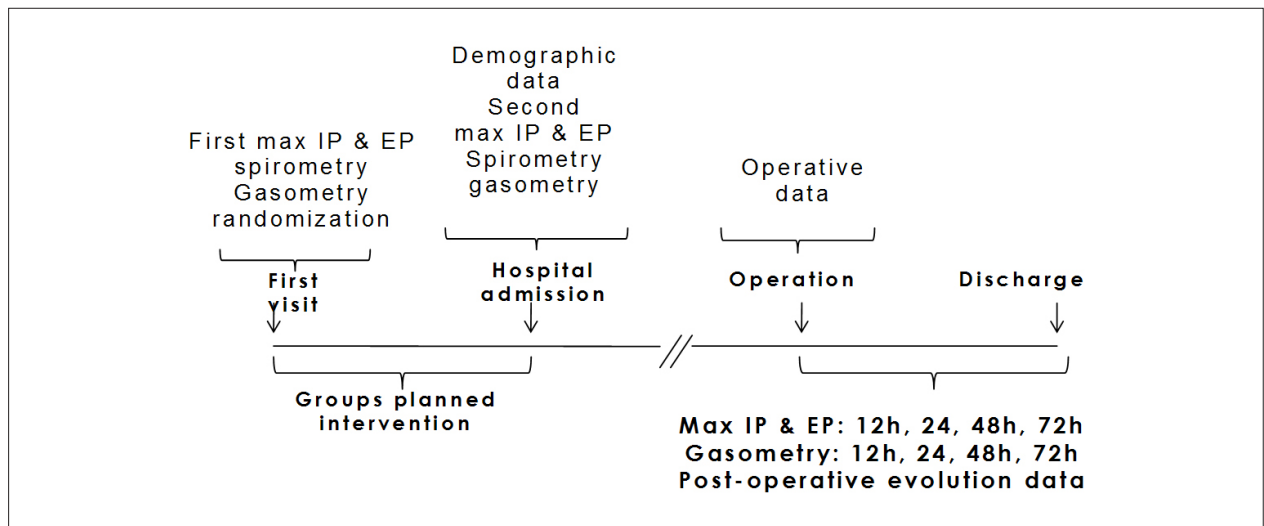


Figure 1 - Timeline of the interventions and data collection.

Committee on Ethics in Research of the University Hospital of the Faculty of Medicine of Ribeirão Preto, University of São Paulo (HCFMRP-USP).

The patients were randomly divided into two groups, Control Group (CG) and Respiratory Incentive Group (RI). Both groups received general information, but only the RI group was submitted to respiratory incentive.

The exclusion criteria were: patients with unstable angina pectoris at the moment of selection or during the program, congestive decompensated heart failure, lack of physical or intellectual capacity to adequately perform the prescribed exercises, complex ventricular and uncontrolled arrhythmia, uncontrolled high blood pressure (>140/90mm/Hg), myocardial infarction or cerebrovascular accident (CVA) less than three years ago, high grade atrioventricular blockade or exercise-induced bronchial spasm. Patients submitted to surgical procedures before completing a minimum of two weeks of respiratory muscle training were also excluded.

The program was discontinued for patients complaining of dyspnea, before or after exercise; abdominal or precordial discomfort or pain, or any other symptom self-characterized as anginous; dizziness, vision darkening or any other type of physical or mental discomfort; vomiting or nausea; tachycardia or bradycardia; tiredness severe enough to prevent continuous exercise; cyanosis or mucosal-skin paleness; vertigo, dizziness or loss of consciousness.

Physical therapeutic procedures

Patients in both groups were submitted to the following procedures: a) Manovacuometry; b) Spirometry; c) Collection of arterial blood for arterial gasometry.

Manovacuometry

For manovacuometry evaluations, peak inspiratory and expiratory pressures, MaxIP and MaxEP, respectively, were determined from the residual volume (RV) and total pulmonary capacity¹⁴ (TPC) measured with a

manovacuometer, model MV-150/300 (Ger-Ar Comércio Equipamentos Ltda. São Paulo, Brazil). Three consecutive and technically acceptable measurements were made with minimal intervals of one minute. Determinations producing values with differences >10% were discarded and new ones repeated in order to have three adequate measurements¹⁴. The first MaxIP and MaxEP determination (D0) was carried out at the start of the program, the second, soon after hospital admission for the programmed surgery (DInt) and the others at 12, 24, 48 and 72 hours, (12h PS, 24h PS, 48h PS, 72h PS respectively) after postoperative extubation. The patients were in the bed-seated position and wearing a nasal clip for all postoperative measurements.

Pulmonary function tests

Both groups of patients were submitted to spirometry tests at the start of the program (D0) and at hospital admission, immediately before surgery (DInt). All spirometric determinations were carried out at the Pulmonary Function Laboratory, at the University Hospital of the School of Medicine of Ribeirão Preto, University of São Paulo, by the same professional, in a constant-temperature environment (22°C) using a 9.0 liter spirometer, model GS Plus (Collins, USA).

Arterial gasometry

Blood samples were collected at the first spirometry determination (D0) before the exercise program and again at hospital admission (DInt). Other samples were collected after surgery, respectively, soon after orotracheal extubation and 12, 24 48 and 72 hours after postoperative extubation.

General advice for pre-surgery

Patients in both groups, CG and RI, were advised about surgery and postoperative peculiarities. They were informed about the damaging effects of tobacco smoking and stimulated not to smoke before surgery. Deep-inspiration exercises without special equipment and daily walks up to their

own limits were also suggested to the patients. The same postoperative physical therapeutic procedures were employed in all patients from both groups, according to the necessity and routine programs established by the Physical Therapy Section of the Thoracic and Cardiovascular Surgery Division of the HCFMRP-USP.

Training program for the inspiratory musculature

Patients were instructed to perform five series of 10 calm and deep inspirations with at least one-minute intervals between the series, without feeling tired or sick, with the incentive of a respiratory instrument "Threshold IMT" (Respironics, Cedar Grove, NJ USA), with a load of 40% of MaxIP (D0)¹⁵. The series were to be repeated thrice daily, while waiting for the surgery.

Statistical analysis

All values are expressed as means \pm standard deviations or percentages. The Shapiro-Wilks test was employed to determine normal distributions. The paired Student "t" test for paired and non-paired values, as indicated, was used when variables were normally distributed and continuous. If not, the Mann-Whitney or Wilcoxon tests were used. The Fisher exact test was used to compare proportions. The "Two-Way ANOVA" test compared three or more repeated measurements, intra and inter-groups.

Results

None of the patients had to leave the program due to adverse events. There were no deaths during the program; one patient left the training voluntarily and no one was excluded due to surgery anticipation before at least 15 days of participation. There were no missing values for any collected data.

Demographic data

Table 1 shows the demographic data of patients from both groups. Except for a male prevalence in the control group ($p=0.007$) there were no other significant differences between groups.

Operative data

Duration of aorta clamping was significantly higher in the RI group (92.07 ± 31.03 versus 73.5 ± 26.98 , $p=0.034$). There were no differences in the periods of extra-corporeal circulation (111.6 ± 74.06 versus 112.3 ± 4.5 , $p=0.696$) and in the number of distal anastomoses in revascularizations (2.8 ± 0.77 versus 3.0 ± 0.87 , $p=0.656$). Myocardial revascularization was performed in 73.3% of the control group patients and in 60.0% of the RI ones ($p=0.700$).

Respiratory function

Regarding the RI group, the time period between patients' inclusion in the program and admission for surgery, that is, the time available for respiratory musculature training, was 154.0 ± 87.4 days.

Table 1 - Demographic data of patients in the control (CG) and respiratory incentive (RI) groups. Data expressed as means \pm SD or percentages

	CG n= 15	RI N= 15	P
Sex			
Male	13 (86.7%)	9 (60%)	0.007
Female	2 (13.3%)	6 (40%)	
Age (years)	63.07 \pm 7.93	62.47 \pm 6.06	0.818
BMI	28.34 \pm 3.16	26.60 \pm 5.17	0.815
Smoker	1 (6.7%)	3 (20%)	0.598
Ex-smoker	4 (26.7%)	4 (26.7%)	1.000
Functional class (NYHA)			
Class I	10 (66.7%)	7 (46.7%)	0.462
Class II	3 (20%)	5 (33.3%)	0.682
Class III	2 (13.3%)	2 (13.3%)	1.000
Class IV	0 (0%)	1 (6.7%)	1.000
EF < 35	0 (0%)	2 (13.3%)	0.483
Chronic atrial fibrillation	3 (20%)	3 (20%)	1.000
Arterial hypertension	10 (66.7%)	10 (66.7%)	1.000
Heart failure	0	1 (6.7%)	1.000
Previous myocardial infarction	7 (46.7%)	4 (26.7%)	0.256
Pulmonary systolic pressure > 40 mmHg	0	3 (20%)	0.224
Diabetes mellitus	6 (40%)	6 (40%)	1.000
Carotid artery obstruction	0	1 (6.7%)	1.000
Obstructive pulmonary disease	1 (6.7%)	1 (6.7%)	1.000
Restrictive pulmonary disease			
Mild	0	1 (6.7%)	1.000
Moderate	0	1 (6.7%)	1.000
Cerebral vascular accident	0	2 (13.3%)	0.483
Peripheral vascular disease	0	1 (6.7%)	0.215

BMI - body mass index; EF - ejection fraction.

Spirometry

Table 2 shows spirometry values for the control group at the beginning of the program, at hospital admission and before surgery. When comparing the spirometric values in the RI group, before and after the training period, one observes significant increases, both in absolute values and in percentages of the predictive forced vital capacity (FVC). The same was observed in absolute values of maximum voluntary ventilation (MVV), but with no significant increase in the predictive percentage. There was a significant decrease in the FEV1/FVC ratio, as FVC was increased and the forced expiratory volume after 1 second (FEV1) did not change. However, the decrease was not significant when compared to the predicted percentile of the FEV1/FVC ratio.

Table 2 - Spirometry values for both groups of patients, CG and RI, measured at the start of the program (D0) and at the time of hospital admission (DInt). Values are expressed as means \pm SD. The paired Student "t" test was employed to compare D0 and DInt for each group

	Control Group (CG)			Respiratory Incentive Group (RI)		
	D0	DInt	p	D0	DInt	p
FVC	3.2 \pm 0.7	3.2 \pm 0.74	0.843	2.9 \pm 1.14	3.1 \pm 1.6	0.006
FVC (predicted %)	88.1 \pm 13.8	92.1 \pm 23.73	0.480	86.3 \pm 21.06	95.7 \pm 21.5	0.002
FRC	3.3 \pm 0.8	3.5 \pm 0.82	0.369	3.5 \pm 1.03	3.3 \pm 1.4	0.307
FRC (predicted %)	104.8 \pm 25.9	111.6 \pm 22.36	0.235	115.3 \pm 23.69	105.9 \pm 31.7	0.230
RV	2.8 \pm 0.7	3.0 \pm 0.78	0.548	2.7 \pm 0.51	2.4 \pm 0.8	0.077
RV (predicted %)	143.4 \pm 36.0	148.4 \pm 29.99	0.571	144.2 \pm 22.04	109.3 \pm 51.3	0.079
TPC	6.1 \pm 1.4	6.23 \pm 1.36	0.364	5.8 \pm 1.57	5.6 \pm 1.8	0.208
TPC (predicted %)	106.8 \pm 19.4	112.1 \pm 19.15	0.224	107.6 \pm 20.7	100.8 \pm 19.5	0.157
MVV	79.4 \pm 24.5	72.9 \pm 30.37	0.278	76.0 \pm 34.37	83.1 \pm 35.9	0.044
MVV (predicted %)	75.5 \pm 18.8	70.1 \pm 22.42	0.343	73.9 \pm 22.72	81.8 \pm 23.4	0.075
FEV1	2.4 \pm 0.6	2.4 \pm 0.61	0.800	2.3 \pm 0.89	2.4 \pm 0.9	0.453
FEV1 (predicted %)	92.3 \pm 17.1	93.3 \pm 21.19	0.743	92.9 \pm 22.29	97.7 \pm 23.0	0.246
FEV1/FVC	75.1 \pm 9.6	73.8 \pm 9.56	0.460	79.7 \pm 5.68	76.2 \pm 6.2	0.008
FEV1/FVC (predicted %)	103.4 \pm 14.	103.0 \pm 12.04	0.925	109.0 \pm 10.07	102.9 \pm 11.7	0.097
FEF 25-75%	2.1 \pm 1.0	2.1 \pm 1.06	0.817	2.4 \pm 1.14	2.2 \pm 1.3	0.216
FEF 25-75% (predicted %)	78.6 \pm 38.3	75.7 \pm 33.16	0.720	88.6 \pm 34.45	83.0 \pm 40.2	0.377
FEF 50%	2.6 \pm 1.7	2.5 \pm 1.35	0.777	3.5 \pm 1.56	3.4 \pm 1.8	0.750
FEF 50 % (predicted %)	57.1 \pm 36.6	55.0 \pm 28.11	0.815	71.5 \pm 28.96	72.0 \pm 36.7	0.951
FEF 75 %	0.74 \pm 0.4	0.68 \pm 0.34	0.427	1 \pm 0.47	0.94 \pm 0.48	0.532
FEF 75 % (predicted %)	43.6 \pm 22.3	41.45 \pm 20.74	0.623	50.44 \pm 22.4	49.66 \pm 24.8	0.861
				3	9	

FVC - forced vital capacity; FRC - functional residual capacity; RV - residual volume; TPC - total pulmonary capacity; MVV - maximal voluntary ventilation; FEV1 - forced expiratory volume after one second; FEF - forced expiratory flow.

Manovacuometry

There was no significant difference between groups concerning Max IP and Max EP. However, in both groups, Max IP was significantly increased when comparing values at hospital admission with the ones determined on D0, considered as control values in each group (Figure 2). All determinations of postoperative MaxIP were significantly lower ($p < 0.001$). MaxEP evolution was similar to MaxIP, as demonstrated in Figure 3, except that there was no difference between the first determination (D0) and the one on the day of hospital admission. However, the decrease in the postoperative determinations was significant, when compared to D0 ($p < 0.001$).

Gasometry

Figure 4 shows that the temporal evolution of arterial PO₂ was not different between the two groups. There was a significant PO₂ increase ($p < 0.001$) in both groups, immediately after extubation when compared to D0, due to routine oxygen supplementation to all patients at this

time. However, values returned to levels similar to D0 in further determinations during the postoperative period. Temporal evolution of PCO₂ shown in Figure 5 does not indicate differences between groups. In addition, the PCO₂ arterial values were kept in the normal range and developed in similar manner. In both groups a significant decrease of arterial PCO₂ was evident after 48 and 72 hours, in comparison to D0, but the values were still within the normality range.

Postoperative clinical evolution

Table 3 shows the incidence of complications and postoperative mortality rates in each group. Although the differences were not significant, there were four deaths (up to 30 days after hospital release). Of these, three occurred in the RI group: one due to aortoiliac thrombosis, the second was a sudden death of undisclosed cause and the third was caused by postoperative pneumonia. The only death in the control group was due to refractory heart failure in the immediate postoperative period. All these patients presented left ventricular dysfunction in preoperative

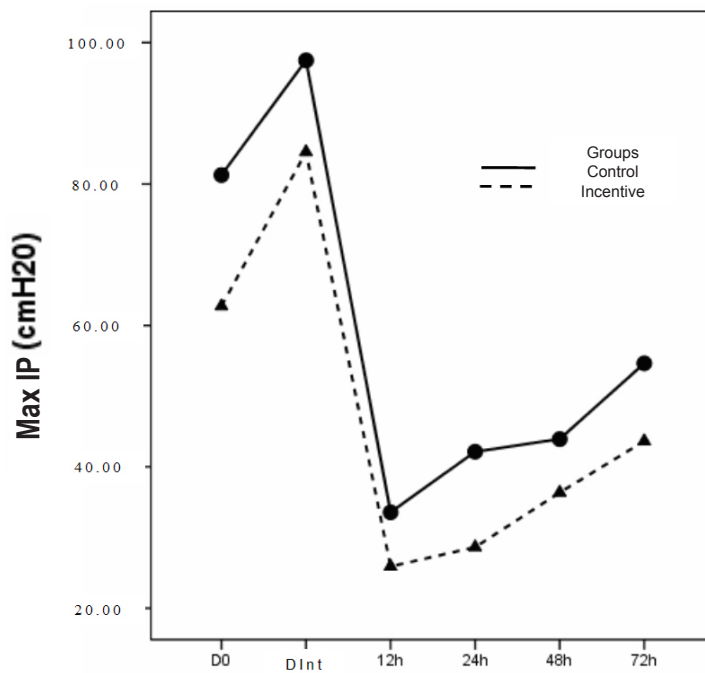


Figure 2 - Variations in the peak inspiratory pressure (Max IP) at the start of the program (D0), at the day of hospital admission and 12, 24, 48 and 72 hours postoperatively in both CG and RI groups. * significant difference ($p < 0.001$) in relation to D0 in the same group.

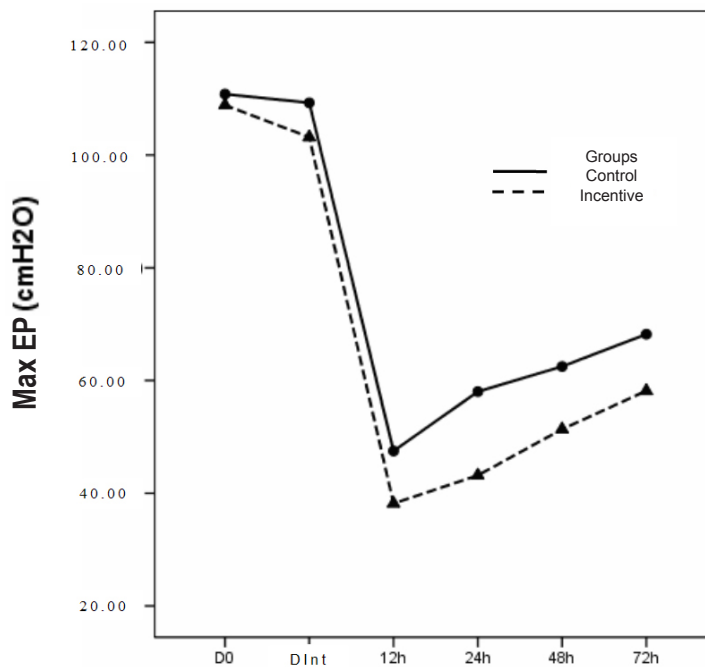


Figure 3 - Variations in the peak expiratory pressure (Max EP) at the start of the program (D0), at the day of hospital admission and 12, 24, 48 and 72 hours postoperatively in both CG and RI groups. * significant difference ($p < 0.001$) in relation to D0 in same group.

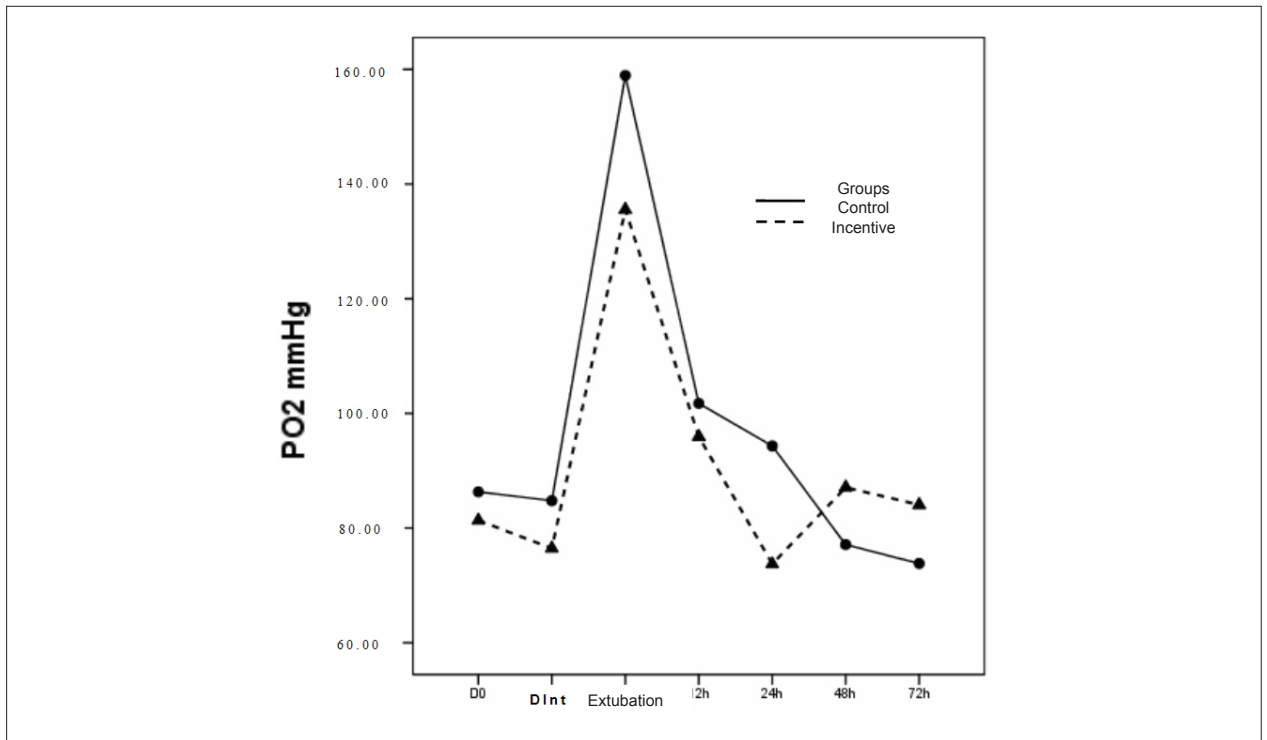


Figure 4 - PO₂ temporal evolution at the start of the program (D0), on the hospital admission day (DInt), soon after orotracheal extubation and 12, 24, 48 and 72 hours postoperatively in both control (CG) and respiratory incentive (RI) groups. * significant difference ($p < 0.001$) in relation to D0 in the same group.

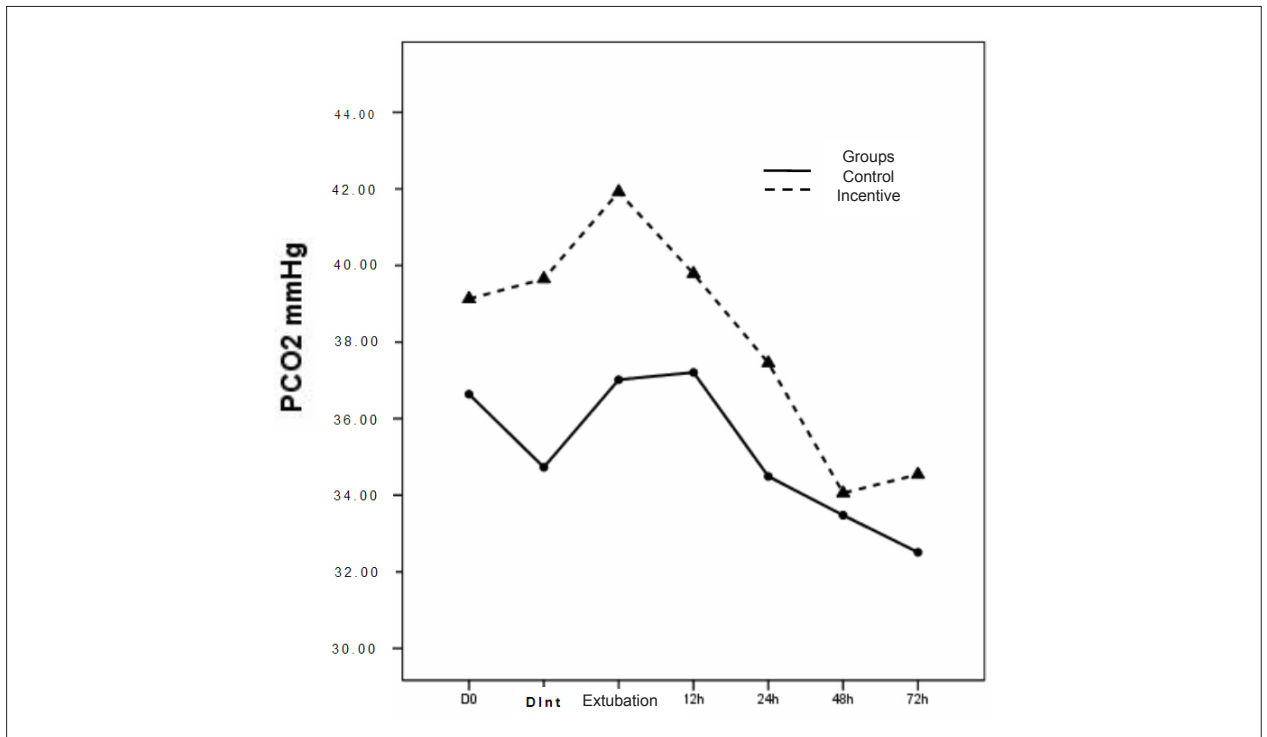


Figure 5 - PCO₂ temporal evolution at the start of the program (D0), on the hospital admission day (DInt), soon after orotracheal extubation and 12, 24, 48, and 72 hours postoperatively in both control (CG) and respiratory incentive (RI) groups. * significant difference ($p < 0.001$) in relation to D0 in the same group.

Table 3 - Postoperative clinical evolution

	Groups		P
	CG n= 15	RI n= 15	
Pneumonia	0	1 (6.7%)	1.000
Prolonged ventilation (> 48h)	0	1 (6.7%)	1.000
Renal failure	0	3 (20%)	0.224
Heart failure	1 (6.7%)	1 (6.7%)	1.000
Deaths	1 (6.7%)	3 (20%)	0.598

period (ejection fraction ≤ 0.35 and/or Functional Class III/IV of NYHA).

Discussion

Although the results of the preoperative muscular inspiratory training did not show apparent clinical benefits, it significantly improved the ventilation function, as judged by the increased forced vital capacity and the maximum voluntary ventilation.

As expected, the inspiratory musculature training did not influence MaxEP. However, the increase in MaxIP was significant at the hospital admission day in comparison to the first value (D0) determined in both groups. Although the only group that showed ventilatory function benefits was the one receiving training, as shown by the spirometry values at hospital admission, the improvement in the MaxIP regardless of training suggests that a previous methodological knowledge by the patients could have contributed to better testing conditions at hospital admission. Similar results were reported by Newall et al¹⁶, in their control patients, although their argumentation was that high-intensity exercises without load performed by the control patients could have improved the inspiratory function expressed by high Max IP also in this group.

In the present study, the control group did not have a specific training of the inspiratory musculature, but they were equally advised to stop smoking, practice daily walking exercises, in addition to receiving instructions for deep respiratory exercises, consisting of 3 series of 10 repetitions, daily, without apparatus.

It is possible that these measurements and exercises, even without loads, may have contributed to the improvement in the MaxIP in the control group. The lack of alterations in the spirometric values in this group reinforces the hypothesis that previous knowledge of the manovacuometry technique influenced the obtaining of Max IP values.

The positive effects of the inspiratory musculature training on pulmonary ventilation were demonstrated by the elevated forced vital capacity (FVC) and maximal voluntary ventilation (MVV), although clinical benefits were not apparent. However, considering that several of the voluntary patients did not present pulmonary dysfunction, it is difficult to show clinical benefits. Nevertheless, other studies^{11,12,17} have

suggested the preoperative training as a preventive factor of respiratory complications, as well as in clinical situations such as heart failure, improving dyspnea sensations, with the possibility of increasing walking distances and resulting in a better quality of life¹⁸.

One aspect of the program, which cannot be controlled by the organizers, is the time period from the start of the program to hospital admission for surgery. As in many other Brazilian institutions, the repressed demand for cardiac surgeries funded by the Federal Health Services (SUS) is very high, resulting in long waiting periods and decreased motivation among the patients. Some authors have considered^{16,18} that the effects of respiratory training may last for several weeks after finishing the training and this may explain the positive spirometry results in a population whose adherence to the program diminished with time.

The significant postoperative reduction in the respiratory musculature performance was expected, as reflected by lower values in MaxEP and IP in both groups. Pain, the effects of cardiac surgery on muscular function and the effect of pain relievers are probable contributors to these findings. As mentioned before, the high PO₂ at extubation was probably due to oxygen supplementation within the first 12 hours after surgery. The arterial PCO₂ reduction observed 48 and 72 hours postoperatively has no clinical value, as it is within the normality range.

Perioperative respiratory training is considered beneficial by several surgeons and physical therapists, especially in the postoperative period, although there is no consensus on its prophylactic efficacy. Contrarily, Pasquina et al¹⁹, concluded in a recent review that the prophylactic respiratory physical therapy is ineffective to prevent post-cardiac surgery pulmonary complications. In addition to complaining about the quality of some of the studies, the authors considered that there is not enough evidence to warrant the usefulness of these procedures. Thus, prospective studies about the prophylactic character of respiratory physiotherapy are in demand. The prospective study of Leguisamo et al²⁰ found that a preoperative program of physical therapy resulted in significant reduction in the hospital stay duration²⁰.

The present study, although prospective with a random choice of voluntary patients, is not criticism-free. The number of subjects is small especially considering the two kinds of cardiac surgery. In addition, lack of strict monitoring may have compromised the efficacy of the program, undermining its clinical benefits.

The fact that just one intervention and one modality of respiratory exercise were used is another possible characteristic bound to be criticized.

Whether the improvement in some spirometric parameters seen after inspiratory muscular training is to be translated into clinical benefits is a question that demands further clinical studies involving a considerable greater number of subjects.

In conclusion, the study showed that the muscular inspiratory training program may be conducted at home, is safe

and resulted in improved forced vital capacity and maximal voluntary ventilation, although its clinical benefits have not been demonstrated.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

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