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Original article

Inspiratory muscle training on sleep quality after coronary artery bypass grafting

Treinamento dos músculos inspiratórios na qualidade do sono após a cirurgia de revascularização do miocárdio

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ABSTRACT

Objective: To evaluate the impact of Inspiratory Muscle Training (IMT) on sleep quality and pulmonary function after Myocardial Revascularization (MR). **Methods:** This is a randomized and controlled clinical trial. The participants were randomized to the inspiratory muscle training group (TG) or to the control group (CG). The CG performed the application of non-invasive ventilation, breathing exercises, kinesiotherapy, cycle ergometry and ambulation. The TG patients, in addition to the unit's standard protocol, were submitted to MIP assessment and started inspiratory muscle training with 40% of MIP. Pulmonary function (vital capacity and peak expiratory flow), ventilatory muscle strength (maximum inspiratory pressure and maximal expiratory pressure) and sleep quality (Pittsburgh Sleep Quality Index (PSQI) and Epworth Sleepiness Scale (EPS)) were evaluated before surgery and at hospital discharge. **Results:** 102 patients participated in this study, 54 people in the CG and 48 in the GT. The IMT had a more relevant impact on sleepiness at hospital discharge (95%CI 7 (6.39 to 7.61) in ESP and PSQI with 95%CI of 8 (7.61 to 8.39). Performed the inspiratory muscle training had a statistically significant response in the variables MIP (95%CI of 18(17.14 to 18.86)), MEP 95%CI of 6(5.37 to 6.63), CV with 95%CI of 2(1.61 to 2.39). On the other hand, PEF showed no difference between the groups with 95%CI of -5(-11.78 to 1.78). **Conclusion:** IMT was effective in reducing the loss of ventilatory muscle strength and sleep quality after CABG.

Keywords: breathing exercises; sleep; cardiac surgery.

RESUMO

Objetivo: Avaliar o impacto do treinamento muscular inspiratório (TMI) na qualidade do sono e na função pulmonar após a revascularização do miocárdio (RM). **Métodos:** Este é um ensaio clínico randomizado e controlado. Os participantes foram randomizados para o grupo de treinamento muscular inspiratório (TG) ou para o grupo controle (GC). O GC realizou a aplicação de ventilação não invasiva, exercícios respiratórios, cinesioterapia, cicloergometria e deambulação. Os pacientes do TG, além do protocolo padrão da unidade, foram submetidos à avaliação da PImáx e iniciaram o treinamento muscular inspiratório com 40% da PImáx. A função pulmonar (capacidade vital e pico de fluxo expiratório), a força muscular ventilatória (pressão inspiratória máxima e pressão expiratória máxima) e a qualidade do sono (Índice de Qualidade do Sono de Pittsburgh (PSQI) e Escala de Sonolência de Epworth (EPS) foram avaliadas antes da cirurgia e na alta hospitalar. **Resultados:** 102 pacientes participaram deste estudo, 54 pessoas no GC e 48 no GT. O TMI teve um impacto mais relevante na sonolência na alta hospitalar (IC95% 7 (6,39 a 7,61) na EPS e PSQI com IC95% de 8 (7,61 a 8,39). A realização do treinamento muscular inspiratório teve uma resposta estatisticamente significativa nas variáveis PImáx (IC95% de 18(17,14 a 18,86)), PEmáx com IC95% de 6(5,37 a 6,63), CV com IC95% de 2(1,61 a 2,39). Por outro lado, o PFE não mostrou diferença entre os grupos com IC95% de -5 (-11,78 a 1,78). **Conclusão:** O treinamento muscular inspiratório foi eficaz na redução da perda de força muscular ventilatória e da qualidade do sono após a cirurgia de revascularização do miocárdio.

Palavras-chave: exercícios respiratórios; sono; cirurgia cardíaca.

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Introduction

Cardiac surgery is considered a complex procedure in the treatment of cardiovascular diseases, but it is associated with complications that may arise from a decline in pulmonary function and inspiratory muscle strength [1]. In this scenario, inspiratory muscle training (IMT) can be useful to optimize muscle and lung function, decreasing postoperative complications. Patients with sleep disorders may be less responsive to training, thus increasing postoperative risk [2].

In 2018, in Brazil, approximately 23,000 heart surgeries (CC) were performed, including plasties and valve replacements and myocardial revascularization, among which more than a thousand deaths were recorded [3].

Physiotherapy is important to prevent pulmonary complications, and one of the techniques used that has positive results is IMT, showing benefits such as significantly improving inspiratory muscle strength, resistance, forced vital capacity, forced expiratory volume in a second, postoperative hospital stay and reduced risk of postoperative pulmonary complications [4].

During the length of stay in the ICU, studies point to an incidence of up to 47% in hospitalized patients who have a lower pain tolerance, greater irritability and longer hospital stay. It is highlighted that ensuring adequate sleep is one of the factors that favor recovery from aggravation that led to hospitalization, since they show that the presence of insomnia causes the second most frequent subjective complaint of patients after pain, which can worsen the underlying disease and affect daytime functioning, being less receptive to prescribed exercises such as IMT [5,6].

Despite the few articles on the subject, this study aims to evaluate the impact of inspiratory muscle training on sleep quality and pulmonary function in patients undergoing coronary artery bypass grafting.

Methods

Design of study

This is a randomized and controlled clinical trial, carried out with patients submitted to coronary artery bypass grafting at the Instituto Nobre de Cardiologia in Feira de Santana, Bahia, from January 2018 to February 2020. This study is registered in the Brazilian Registry of Clinical Trials (ReBEC) with the number RBR-8dqrdq.

Inclusion and exclusion criteria

The following inclusion criteria were used: Individual of both sexes with Coronary Artery Disease (CAD), aged over 18 years and undergoing coronary artery bypass grafting with cardiopulmonary bypass and median sternotomy. The exclusion criteria were the use of an intra-aortic balloon, surgical reintervention, death, valvular heart disease, previous lung disease, inability to understand how to perform the proposed techniques, hemodynamic instability during the evaluation or during inspiratory muscle training, physical limitation, such as amputation, that compromised the performance of the exercises and inability to answer the applied questionnaires.

Sample calculation

In order to calculate the sample size, we carried out a pilot study with 10 patients. We used a standard deviation of 63 meters, in the six-minute walk test, based on the pilot of the final individualized IMT group and 112 meters in relation to the standard deviation of the conventional IMT group from the work of Cordeiro *et al*. [7] We used a difference of 50, which is related to the clinically relevant distance [7]. For an alpha of 5% and aiming to reach a power of 80%, 42 patients were needed, 21 in each group.

Ethical aspects

Our study was submitted to and approved by the Ethics and Research Committee of *Faculdade Nobre de Feira de Santana*, with opinion number 2,366,995. All participants signed an informed consent form.

Study protocol

Research participants were randomized to the inspiratory muscle training group (TG) or to the control group (CG) by a simple draw. There were two balls, each with a piece of paper indicating the groups, and a member of the team on duty was asked to choose one of the balls, the result being the patient's allocation group. No researcher had any influence on the procedures adopted by the team, and the patient was managed based on the institution's protocol, which consists of the application of non-invasive ventilation, breathing exercises, kinesiotherapy, cycle ergometry and ambulation. The TG patients, in addition to the unit's standard protocol, underwent MIP assessment and started inspiratory muscle training with a linear pressure loading device (*PowerBreathe Knectic Series®, HaB International, UK*), with 40% of MIP, performing 3 sets with 15 repetitions. This training was performed twice a day, from the first postoperative day until the day of hospital discharge. Pulmonary function, ventilatory muscle strength and sleep quality were assessed before surgery and at hospital discharge.

Clinical and surgical characteristics such as diabetes mellitus, systemic arterial hypertension, dyslipidemia, acute myocardial infarction and sedentary lifestyle were collected. All these comorbidities were known through the medical records of each patient, with the exception of sedentary lifestyle, which was assessed using the International Physical Activity Questionnaire (IPAQ) in long format, and evaluates 27 questions related to physical activities performed in a normal week, with light intensity, moderate and vigorous with a continuous duration of 10 minutes, divided into four categories of physical activity such as work, transportation, domestic activities and leisure. Those who did not perform any physical activity for at least 10 continuous minutes during the week were considered sedentary [8].

Measurement of ventilatory muscle strength

The preoperative assessment of inspiratory muscle strength (Maximum Inspiratory Pressure (MIP)) was performed with an *Indumed®* analog manovacuometer. During the evaluation, a maximum expiration was requested until the residual volume and then a maximum and slow inspiration until the total pulmonary capacity. This test was done through the method with the unidirectional valve, being possible a flow through an orifice of one millimeter in order to exclude the action of the buccinator, and repeated 3 times, using the highest value reached since this value was not the last. Expiratory muscle strength (Maximum Expiratory Pressure (MEP)) was evaluated with the same device and the patient was instructed to perform a maximum inspiration until he reached his Total Pulmonary Capacity, the mask was placed and after this required a maximum expiration until the residual capacity was reached. The test was repeated three times, using the result with the highest value, which could not be the last [9].

Pulmonary function assessment

To assess vital capacity, a facemask connected to the expiratory branch of the analog ventilometer (*Ferraris – Mark 8 Wright Respirometer, Louisville, CO, USA*) was used and the patient was instructed on all phases of the test. The ventilometer was unlocked, reset to zero and soon after the facemask was placed on the individual's face. He performed a deep inspiration until reaching his total pulmonary capacity, soon after a slow and gradual expiration until reaching his residual volume. After that, the ventilometer was stopped and the result observed and noted. The test was repeated three times, considering the highest value result [10].

Peak expiratory flow was assessed using the *Mini Wright®* brand peak flow. During the assessment, the patient was seated, with the head in a neutral position and a nose clip to prevent air from escaping through the nostrils. The patient took a deep inspiration, up to full lung capacity, followed by forced expiration with the mouth on the device. After three measurements, the highest value was chosen, with no difference greater than 40 liters between measurements [10].

Sleep quality assessment

For the assessment, the Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale were used.

The Pittsburgh Sleep Quality Index Questionnaire (PSQI) was developed, and validated in Brazil, in an adult population, by Bertolazi. The PSQI analyzes seven sleep components: subjective quality, sleep latency, sleep duration, sleep efficiency, and sleep disorders, medication use and daily dysfunction roommate. The score can vary from 0 to 3 in each question, when adding the questions, a maximum score of 21 points is reached. Scores from 0-4 indicate good sleep quality, 5-10 indicate poor sleep quality, and scores above 10 indicate a sleep disorder [11].

The Epworth Sleepiness Scale is used to assess the degree of excessive daytime sleepiness. Eight questions are asked, which can be scored from 0 to 3 and the maximum total score goes up to 24, with 0-6 indicating normal sleep, 7-8 average sleepiness and 9-24 abnormal sleepiness [12].

Statistical analysis

For data analysis, the Statistical Package for Social Sciences (SPSS) version 20.0 was used. Normality was verified using the Shapiro-Wilks test. Continuous variables were expressed as mean and standard deviation. Chi-square was used to compare categorical variables. The analysis between groups was performed using the independent Student's t test and intra-group using the paired Student's t test. A delta was generated by subtracting the hospital discharge values from the preoperative period. A $p<0.05$ was considered significant.

Results

One hundred and two patients participated in this study, 54 in the control group and 48 in the inspiratory muscle training group (Figure 1), mean age 66 years, most of the patients were male 62 (60.5%), BMI between 24 and 25 kg/m², and the most common comorbidity was systemic arterial hypertension with 47 patients (47.5%), other data are shown in table I.

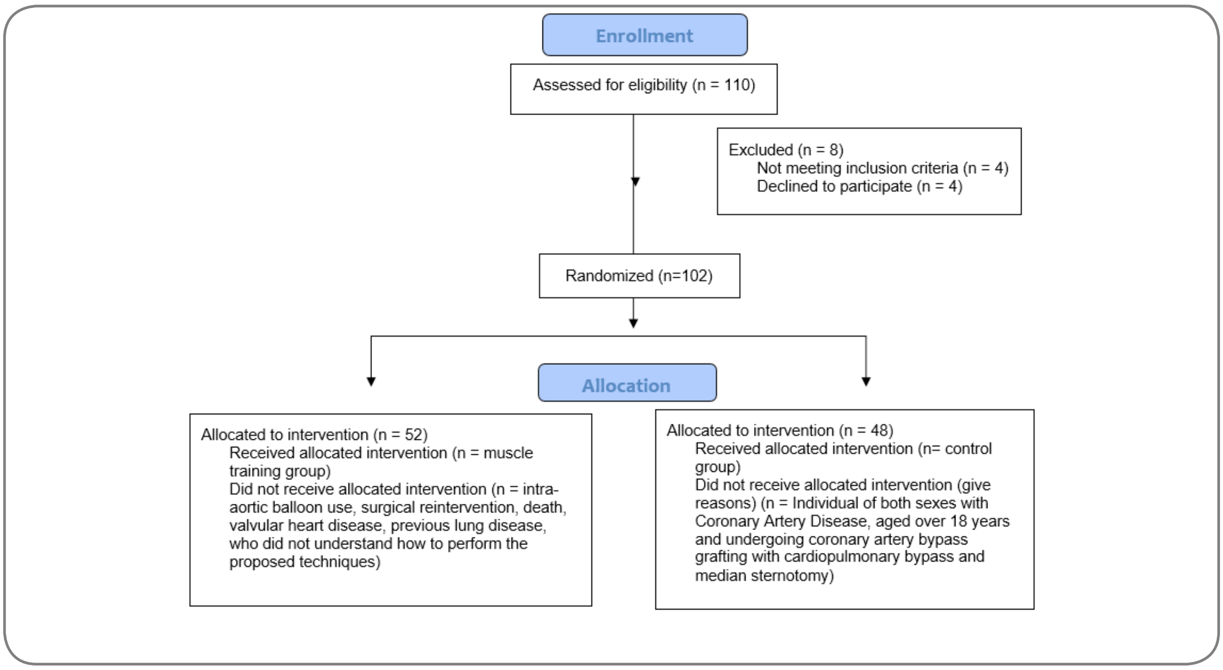

Figure 1 - Patient flow throughout the study

Table I - General data of the patients

Variable	Control Group (n = 54)	IMT Group (n = 48)	p
Age (years)	64 ± 6	67 ± 5	0.53 [a]
Gender			0.43 [b]
Male	33 (61%)	29 (60%)	
Female	21 (39%)	19 (40%)	
BMI (kg/m²)	24 ± 3	25 ± 4	0.64 [a]
Smoking history	5 (9%)	6 (13%)	0.43 [b]
Ejection fraction (%)	56 ± 7	54 ± 5	0.68 [a]
Comorbidities			
SAH	25 (46%)	22 (49%)	0.68 [b]
DM	18 (33%)	17 (35%)	0.86 [b]
DLP	16 (30%)	12 (25%)	0.54 [b]
Surgery time (hours)	4.4 ± 1.6	4.3 ± 1.9	0.76 [a]
Time of ICU stay (days)	2 ± 2	2 ± 1	0.87 [a]
Time of hospital stay (days)	9 ± 3	8 ± 2	0.53 [a]
MV time (hours)	8 ± 3	7 ± 2	0.86 [a]
Number of drains	2 ± 1	2 ± 1	0.93 [a]
Number of grafts	2 ± 1	2 ± 1	0.94 [a]

a = Independent Student's t-test; b = Chi-square; IMT = Inspiratory Muscle Training; BMI = Body Mass Index; SAH = Systemic Arterial Hypertension; DM = Diabetes Mellitus; DLP = Dyslipidemia; ICU = Intensive Care Unit; MV = Mechanical Ventilation

Table II shows the comparison between preoperative and hospital discharge on two questionnaires, the Pittsburgh Sleep Quality Index and the Epworth Sleepiness Scale. It can be see that the group that received IMT had a more relevant impact on sleepiness at hospital discharge (95%CI 7 (6.39 to 7.61) on the ESP and on the PSQI with a 95%CI of 8 (7.61 to 8.39).

Table II - Findings from the questionnaires in our study

Questionnaires	Control group (n = 54)	IMT Group (n = 48)	95%CI	p [a]
ESS (0 - 24)				
Preoperative	13 ± 4	12 ± 4	1 (-0.57 a 2.57)	0.76
Hospital discharge	5 ± 2 [b]	11 ± 3	-6 (-4.99 a -7.01)	<0.01
Δ	8 ± 2	1 ± 1	7 (6.39 a 7.61)	<0.01
PSQI (0 - 21)				
Preoperative	11 ± 3	10 ± 3	1 (-0.18 a 2.18)	0.83
Hospital discharge	4 ± 2 [b]	11 ± 2	-7 (-6.21 a -7.79)	<0.01
Δ	7 ± 1	-1 ± 1	8 (7.61 a 8.39)	<0.01

A = Teste t de Student independente; b = Teste T de Student pareado com p < 0,05 comparando o pré-operatório com a alta hospitalar; IC = Intervalo de confiança; ESS = Escala de sonolência de Epworth; PSQI = Índice de qualidade do sono de Pittsburgh; IMT =Treinamento muscular inspiratório

Table III - Pulmonary function and muscle strength test findings in our study

Variable	Control group (n = 54)	IMT Group (n = 48)	95%IC	p[a]
MIP (cmH_2O)				
Preoperative	112 ± 8	110 ± 9	2 (-1.36 a 5.36)	0.78
Hospital Discharge	98 ± 5	78 ± 8[b]	20 (17.34 a 22.66)	<0.01
Δ	14 ± 3	32 ± 1	18 (17.14 a 18.86)	<0.01
MEP (cmH_2O)				
Preoperative	90 ± 6	92 ± 9	- 2 (-5.04 a 1.04)	0.89
Hospital Discharge	73 ± 7	69 ± 7[b]	4 (1.25 a 6.75)	0.04
Δ	17 ± 1	23 ± 2	6 (5.37 a 6.63)	0.03
VC (ml/kg)				
Preoperative	56 ± 5	54 ± 7	2 (-4.42 a 0.42)	0.92
Hospital Discharge	49 ± 6	45 ± 6	4 (1.64 a 6.36)	0.04
Δ	7 ± 1	9 ± 1	2 (1.61 a 2.39)	0.05
PEF (L/min)				
Preoperative	415 ± 108	410 ± 112	5 (-48.35 a 38.35)	0.87
Hospital discharge	377 ± 87[b]	367 ± 99[b]	-10 (-26.82 a 46.82)	0.32
Δ	38 ± 21	43 ± 13	-5 (-11.78 a 1.78)	0.53

a = Independent Student's T test; b = Paired Student's T test with $p < 0.05$ comparing preoperative with hospital discharge; CI = Confidence Interval; IMT = Inspiratory Muscle Training; MIP = Maximal Inspiratory Pressure; MEP = Maximal Expiratory Pressure; VC = Vital Capacity; PEF = Peak Expiratory Flow

Discussion

Based on the data observed in the results, we can analyze that the inspiratory muscle training performed in patients after cardiac surgery had an impact on the improvement of daytime sleepiness and sleep quality, evaluated through the Epworth Sleepiness Scale and Pittsburgh sleep quality index, respectively. In addition, we found that there was less loss of inspiratory and expiratory muscle strength and vital capacity in the group of patients exposed to IMT.

We know that some factors can negatively affect the quality of sleep in ICU patients. Factors such as brightness, noise, alarms, and respiratory discomfort are the main reports in the literature [13]. Muscle weakness can generate a biomechanical disadvantage, increasing ventilatory demand, which leads to respiratory discomfort. Thinking about the application of a protocol, IMT contributes to the decrease of this disadvantage. For this reason, we noticed that the group of patients who underwent IMT had better sleep quality and also increased muscle strength.

In 2003, a group from London defended that there was a need to promote sleep improvement after cardiac surgery and that this outcome would be achieved through rest [14]. Currently, our group argues that the performance of exercise, particularly in this study, IMT, is able to modulate sympathetic activity, generating a greater feeling of relaxation after the protocol. This greater relaxation generates a decrease in heart rate and blood pressure, promoting better sleep quality, as seen through the PSQI [15].

Yayla *et al*. [16] had already demonstrated that an early mobilization protocol decreased the length of hospital stay and improved sleep after surgery, a result similar to that verified by our study. Although the results corroborate, the protocol used by Yayla *et al*. [16] consisted of positioning in bed, use of incentive inspirometry, passive and active kinesiotherapy, and transfer to an armchair. This approach is routinely used in our study, with the differential being inspiratory muscle training, i.e., IMT was able to optimize the results already verified in the literature.

The improvement in muscle strength can be attributed to the attenuation of respiratory metaborreflex, increasing blood supply to the periphery and decreasing the energy expenditure of the diaphragm [17]. In addition, exercises performed in accordance with early mobilization practices cause tissue oxygenation levels to increase [16].

Tafelmeier *et al*. [18] showed that the presence of central apnea was associated with increased risk for pulmonary complications after cardiac surgery. In our study, we did not evaluate or stratify the presence or severity of sleep disorders; however, we can infer that the sample included patients with this profile, given the high prevalence of this condition in patients with heart disease.

It is important to understand that other factors can affect sleep during the hospital stay. Among these factors, we can mention the interaction of the staff with the patient to perform some procedure or administer medication. This condition, verified by Casa *et al*. [19], is common between midnight and 6 am. This makes the patient less willing and less active the next day, resulting in a slower recovery of muscle strength and functionality. Within this context, the application of IMT can minimize the loss, as seen in this study, but other interventions need to coincide to optimize postoperative functional capacity.

Although the presence of sleep disorders was not assessed before surgery, Spielmanns *et al*. [20] found that the results obtained during rehabilitation after cardiac surgery were not influenced by the presence of sleep apnea. In the pediatric population the relationship between exercise and sleep quality is already well established [21], but this is the first paper to demonstrate a positive impact of IMT on daytime sleepiness and sleep quality after cardiac surgery.

Ranjbaran *et al*. [22] showed that performing an exercise protocol improved the quality of sleep in patients undergoing CABG, but the study was conducted after hospital discharge. Thus, our study is the first to demonstrate an improvement in sleep quality in patients undergoing cardiac surgery while still in the nosocomial environment.

Our group had already demonstrated that postoperative IMT reduces the loss of ventilatory muscle strength, which has a direct impact on the functional capacity of these patients. In addition, a recent meta-analysis showed that IMT improves inspiratory muscle strength, pulmonary function, and functional capacity, and reduces the length of hospital stay in patients undergoing cardiac surgery [23].

A limitation of the present study is that polysomnography was not used to verify the presence of sleep disorders in patients hospitalized for cardiac surgery. However, it should be emphasized that our aim was not to verify an improvement in the disorder, but in the quality of sleep.

Conclusion

Based on the values found in our study, we conclude that inspiratory muscle training in patients after coronary artery bypass grafting was effective in improving the quality of sleep and lung function in these individuals.

Conflict of interest
This study has no conflict of interest

Sources of financing
There was no funding for the study

Authors' contributions
Conception and design of the research: Cordeiro ALL; Data collection: Cordeiro ALL, Reis BL, Pereira EA; **Data analysis and interpretation:** Cordeiro ALL, Reis BL, Pereira EA; **Statistical analysis:** Cordeiro ALL; **Manuscript writing:** Cordeiro ALL, Reis BL, Pereira EA; **Critical review of the manuscript:** Guimarães ARF

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