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Systematic review

Effects of pre-operative inspiratory muscular training in patients subject to cardiac surgery: a systematic review

Effects of pre-operative inspiratory muscular training in patients subject to cardiac surgery: a systematic review

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ABSTRACT

Introduction: The diseases that affect the cardiovascular system often lead the patient to undergo cardiac surgery in search of better survival. This surgical procedure is associated with a high incidence of postoperative complications related to respiratory function. Preoperative inspiratory muscle training (IMT) can benefit patients who will undergo cardiac surgery. **Objective:** Systematic review of randomized clinical trials, informing the effects of preoperative inspiratory muscle training in patients undergoing cardiac surgery. **Methods:** The search for randomized clinical trials was carried out by two authors, including the Medline, PubMed, PEDro and Scielo databases. The methodological quality of the articles was assessed using the PEDro scale and the risk of bias was scored using the Review Manager version 5.4 software from the Cochrane Collaboration. **Results:** Initially, a total of 85 articles were identified in the databases. Five articles were included for data extraction. The main outcomes of this systematic review are: maximum inspiratory pressure (PImax); forced expiratory volume in the first second (FEV1); forced vital capacity; pneumonia, duration of postoperative hospitalization and postoperative pulmonary complication. **Conclusion:** The IMT performed in the preoperative period adds benefits that include prevention of postoperative pulmonary complications, increasing the PImax and FEV1, reducing the occurrence of pneumonia and reducing the length of postoperative hospital stay.

Keywords: respiratory training; chest surgery; cardiac surgery.

RESUMO

Introdução: As doenças que acometem o sistema cardiovascular levam frequentemente o paciente a realizar cirurgias cardíacas em busca de uma melhor sobrevida. Esse procedimento cirúrgico está associado a uma grande ocorrência de complicações pós-operatórias relacionadas com a função respiratória. A realização do treinamento muscular inspiratório (TMI) pré-operatório pode beneficiar pacientes que serão submetidos a cirurgias cardíacas. **Objetivo:** Revisão sistemática de ensaios clínicos randomizados, informando os efeitos do TMI pré-operatório em pacientes submetidos a cirurgia cardíaca. **Métodos:** A busca dos ensaios clínicos randomizados foi feita por dois autores, incluindo as bases de dados Medline, PubMed, Pedro e Scielo. A qualidade metodológica dos artigos foi avaliada utilizando a escala PEDro e o risco de viés foi pontuado pelo *software Review Manager version 5.4* da *Cochrane Collaboration*. **Resultados:** Inicialmente foi identificado um total de 85 artigos nas bases de dados. Cinco artigos foram incluídos para extração de dados. Os desfechos principais desta revisão sistemática são: Pressão inspiratória máxima (PImáx); Volume expiratório forçado no primeiro segundo (VEF1); Capacidade vital forçada CVF; Pneumonia, duração da internação pós-operatória e complicação pulmonar pós-operatória. **Conclusão:** O TMI realizado no período pré-operatório para pacientes submetidos a cirurgia cardíaca agrega benefícios que incluem prevenção das complicações pulmonares pós-operatórias, aumentando a PImáx e o VEF1, reduzindo a ocorrência de pneumonia e diminuindo o tempo de internação pós-operatória.

Palavras-chave: treinamento respiratório; cirurgia torácica; cirurgia cardíaca.

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Introduction

The conditions that affect the cardiovascular system, more precisely in the valvular region of the heart and in the coronary arteries, can lead the individual to need cardiac surgery [1]. Worldwide, more than 23 million people are affected by this complex syndrome [2]. In 2015, Brazil recorded 91,738 deaths from cardiac complications, an average of 7,645 deaths per month [3].

The cardiac surgical procedure, when combined with factors such as obesity, sedentary lifestyle, smoking, diabetes and pre-existing lung diseases, predisposes to the occurrence of postoperative complications [4]. Thus, in addition to a threat to patient survival, there is a risk of increased length of stay and hospital costs [5]. According to data from the Brazilian Society of Cardiovascular Surgery, Brazil is the second country in the world in number of heart surgeries performed annually, totaling about 102,000 surgeries/year [6].

In this scenario, the performance of the inspiratory muscles is commonly compromised (approximately 50%), reducing lung volumes and capacities, compromising lung compliance, impairing gas exchange and coughing effectiveness [4]. Such changes can also trigger pneumonia and atelectasis [7].

Inspiratory muscle training (IMT) appears, then, as a type of physical exercise for these patients, including indication already in the preoperative period [8]. By conditioning the inspiratory muscles preventively, the consequences of the postoperative period tend to be mitigated, with an expectation of improvement in lung function and consequent optimization of clinical outcomes [7].

Given the relevance of the subject, the objective of this study was to perform a systematic review of randomized clinical trials on the effects of preoperative IMT in patients undergoing cardiac surgery.

Methods

This is a systematic review of the literature, which included and analyzed original studies, such as a randomized clinical trial, on the effects of preoperative respiratory muscle training in cardiac surgeries. The systematic review was planned and conducted in accordance with the recommendations of the Cochrane Collaboration and reported in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews e Meta-Analyses (PRISMA) [9].

Sources of information and research strategies

The studies were identified by the researchers, searching the following databases: Public Medline (PubMed), National Library of Medicine (Medline), Physiotherapy Evidence Database (PEDro) and Scientific Eletronic Library Online (SciELO) from July 2019 to February 2020 publications in Portuguese or English. For the research, the following combinations were used "AND" and "OR" of the following descriptors and their respective counterparts in English: Inspiratory training, Thoracic surgery

associated with Cardiac surgery and Clinical Trial. Registration number PROSPERO: CRD42020205437. Chart 1 presents the manual search strategies.

Chart 1 - Search strategy in the PubMed database

(“inhalation”[MeSH Terms] OR “inhalation”[All Fields] OR “inspiratory”[All Fields]) AND (“muscles”[MeSH Terms] OR “muscles”[All Fields] OR “muscle”[All Fields]) AND (“education”[Subheading] OR “education”[All Fields] OR “training”[All Fields] OR “education”[MeSH Terms] OR “training”[All Fields]) AND (“thoracic surgical procedures”[MeSH Terms] OR (“thoracic”[All Fields] AND “surgical”[All Fields] AND “procedures”[All Fields]) OR “thoracic surgical procedures”[All Fields] OR (“thoracic”[All Fields] AND “surgery”[All Fields]) OR “thoracic surgery”[All Fields] OR “thoracic surgery”[MeSH Terms] OR (“thoracic”[All Fields] AND “surgery”[All Fields])). ((“inhalation”[MeSH Terms] OR “inhalation”[All Fields] OR “inspiratory”[All Fields]) AND (“muscles”[MeSH Terms] OR “muscles”[All Fields] OR “muscle”[All Fields]) AND (“education”[Subheading] OR “education”[All Fields] OR “training”[All Fields] OR “education”[MeSH Terms] OR “training”[All Fields]) AND (“thoracic surgical procedures”[MeSH Terms] OR (“thoracic”[All Fields] AND “surgical”[All Fields] AND “procedures”[All Fields]) OR “thoracic surgical procedures”[All Fields] OR (“thoracic”[All Fields] AND “surgery”[All Fields]) OR “thoracic surgery”[All Fields] OR “thoracic surgery”[MeSH Terms] OR (“thoracic”[All Fields] AND “surgery”[All Fields]))) AND Clinical Trial[ptyp](((“breathing exercises”[MeSH Terms] OR (“breathing”[All Fields] AND “exercises”[All Fields]) OR “breathing exercises”[All Fields] OR (“respiratory”[All Fields] AND “muscle”[All Fields] AND “training”[All Fields]) OR “respiratory muscle training”[All Fields]) AND (“thoracic surgical procedures”[MeSH Terms] OR (“thoracic”[All Fields] AND “surgical”[All Fields] AND “procedures”[All Fields]) OR “thoracic surgical procedures”[All Fields] OR (“thoracic”[All Fields] AND “surgery”[All Fields]) OR “thoracic surgery”[All Fields] OR “thoracic surgery”[MeSH Terms] OR (“thoracic”[All Fields] AND “surgery”[All Fields]))) (((“breathing exercises”[MeSH Terms] OR (“breathing”[All Fields] AND “exercises”[All Fields]) OR “breathing exercises”[All Fields] OR (“respiratory”[All Fields] AND “muscle”[All Fields] AND “training”[All Fields]) OR “respiratory muscle training”[All Fields]) AND (“thoracic surgical procedures”[MeSH Terms] OR (“thoracic”[All Fields] AND “surgical”[All Fields] AND “procedures”[All Fields]) OR “thoracic surgical procedures”[All Fields] OR (“thoracic”[All Fields] AND “surgery”[All Fields]) OR “thoracic surgery”[All Fields] OR “thoracic surgery”[MeSH Terms] OR (“thoracic”[All Fields] AND “surgery”[All Fields]))) AND Clinical Trial[ptyp]

Study selection

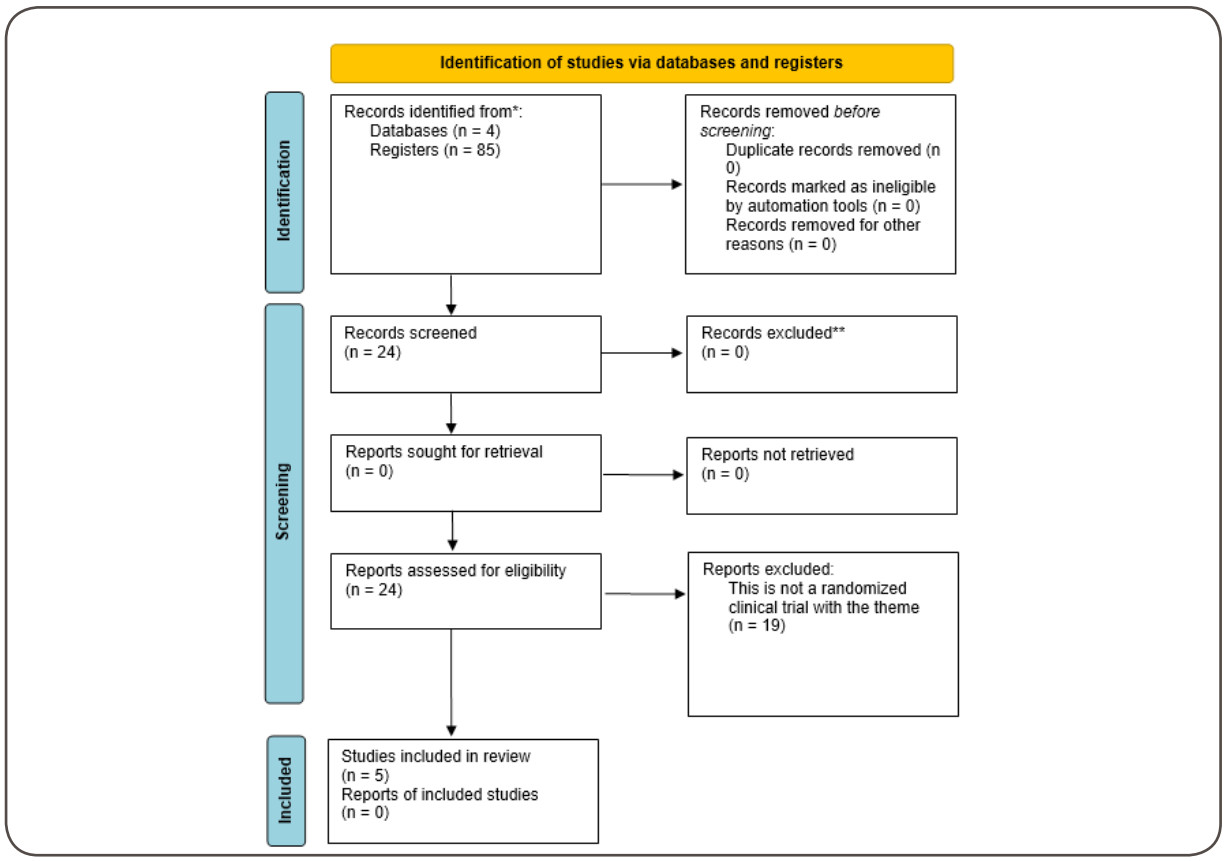

Figure 1 -Search and selection of studies for inclusion in the systematic review according to the PRISMA methodology - 2020

Study eligibility assessment

The titles and abstracts of each data source were evaluated by the researchers, and the studies eligible for the systematic review were defined. If at least one of the researchers considered an eligible reference, the full text was obtained for full reading. The full texts of the selected articles were independently evaluated by the researchers to identify those that met the inclusion or exclusion criteria. The references of each selected article were analyzed to identify other potentially qualified studies. After reading and inclusion, the works were evaluated for the construction of the systematic review.

Methodological quality

The quality of the included articles was assessed using the PEDro scale. This evaluates the tests through 11 pre-established items PEDro [10]. The PEDro score was not used as an inclusion or exclusion criterion for the articles, but as an indicator of scientific evidence of the studies [8,11].

Risk of bias in primary studies

The risk of bias in the studies included in this systematic review was scored using the Review Manager version 5.4 software (REVMAN - Cochrane Collaboration), which is domain-based, with critical assessment done separately for different aspects of the risk of bias of the study type in question [12].

Results

Description of selected studies

Initially, a total of 85 articles were identified in the selected databases (PubMed), (Medline), (PEDro) e (SciELO), reducing to 24 articles, when the "clinical trial" filter was applied, which analyzed the full text. Six articles met the eligibility criteria and were included for data extraction, 1 of which was excluded due to difficult access. The other 17 clinical trials were excluded due to inadequacy, after reading the titles and abstracts.

Methodological quality of studies

Table I - Methodological quality of studies by the Scale PEDro [10]

Author, year	1	2	3	4	5	6	7	8	9	10	11	Total
Chen *et al.*, 2019 [6]	X	X	X	X	X	X	X	X	X	X		9
Ferreira *et al.*, 2009 [13]	X	X		X				X	X	X		5
Hulzebos *et al.*, 2006 [14]	X	X	X	X	X		X	X	X	X		8
Weiner *et al.*, 1998 [15]	X			X				X	X	X		4
Cahalin *et al.*, 1997 [16]	X	X		X				X	X	X		5

1) specification of inclusion criteria (item not scored); 2) random allocation; 3) allocation secrecy; 4) similarity of groups in the initial or baseline phase; 5) masking of subjects; 6) therapist masking; 7) evaluator masking; 8) measurement of at least one primary outcome in 85% of allocated subjects; 9) intention-to-treat analysis; 10) comparison between groups of at least one primary outcome and 11) reporting of measures of variability and estimation of parameters of at least one primary variable.

Table II - General characteristics of the included studies in the Systematic Review

Autor, ano	Type of Cardiac Surgery	Sample(N-IG/CG)	Intervention vs Control	Results	Outcomes
Chen *et al.*, 2019 [6]	Myocardial revascularization graft and/or valve	197- 98/ 99 Patients scheduled for cardiac surgery (graft and/or coronary artery bypass graft) aged ≥ 50 years and able to understand informed consent were eligible.	IG = They received five days of preoperative inspiratory muscle training at 30% of maximal inspiratory pressure. As (Threshold IMT) for 20 minutes in addition to the usual care received by patients in the control group. CG= Usual care (education, coughing and early mobilization) and abdominal breathing training before surgery. They trained using the same protocol as participants in the intervention group for the same number of repetitions, frequency, duration and supervision, but the intensity was fixed at the minimum device load (9 cm H_2O) throughout the training period.	Pulmonary function test Pre-CG MIP = 90,06±22,55 cmH_2O FEV1 = 87,93±16,21% IG MIP =86,93±23,03 cmH_2O FEV1= 88,04±11,85% Post-pulmonary function test CG MIP =93,22±23,12 cmH_2O FEV1= 87,28±14,87% IG MIP =100,08±23,36 cmH_2O FEV1=91,14±15,10%	Primary was the occurrence of postoperative pulmonary complications. Secondary were inspiratory muscle strength, lung function and length of hospital stay.
Rodrigues, Barboza 2009 [13]	Myocardial revascularization surgery and/or valve surgery	30- 15/15 30 patients of both sexes, without ethnic discrimination, under 50 years of age	IG = They were included in a home program of at least 2 weeks of preoperative training of the inspiratory muscles, using a device with a load corresponding to 40% of the maximal inspiratory pressure. CG = Received general guidance and did not train the inspiratory muscle.	Pulmonary function test Pre-CG FVC =3,2±0,7L FEV1=2,4±0,6L IG FVC =2,9±1,14L VEF1=2,3±0,89L Post-pulmonary function test CG FVC =3,2±0,74L FEV1=2,4±0.61L IG FVC =3,1±1,6L FEV1=2,4±0,9L	Primary respiratory muscles are affected after cardiac operations. Clinical secondary as: ventilatory function, forced vital capacity and maximum voluntary ventilation.
Hulzebos *et al.*, 2006 [14]	Myocardial revascularization surgery	279- 140/139 Patients with the ability to understand informed consent were eligible.	IG = They received IMT in the preoperative period of cardiac surgery. CG = Usual treatment in the preoperative period.	Pre-CG MIP = 80,3±31,4 cmH_2O Peak Pressure 50,7 ±14,4% IG MIP =81,1±29,5 cmH2O Peak Pressure 48,8± 15,7% Post-CG MIP =79,5±31,3(p = 0,28) cmH_2O Peak Pressure 51,8 ± 16,4% IG MIP =95,6±31,6 cmH_2O Peak Pressure 56,0±15,1%	The primary feasibility outcome variables were the occurrence of adverse events and patient satisfaction and motivation. Secondary outcome variables were postoperative pulmonary complications and length of hospital stay.

Table II - Continuation

Autor, ano	Type of Cardiac Surgery	Sample(N-IG/CG)	Intervention vs Control	Results	Outcomes
Weiner *et al.*, 1998 [15]	Revascularization of the myocardium	84- 42/42 with ages ranging from 33 to 82 years, they were evaluated before the operation and randomized into two groups.	IG = IMT using a training threshold for 30 min/day for 2 weeks, 1 month before the operation. CG = simulated training.	Pre-CG MIP = 77,8±64,2%, FVC 90,0±62,8 % FEV1=90,0±63,6% IG MIP =76,1±65,0% Post-CG MIP = 75,6±64,8% FEV1=80,0±63,2% FVC=81,1±63,0 (p = 0,001) IG MIP = 87,0±65,2% (p = 0,001)	Myocardial revascularization surgery has a significant deteriorating effect on inspiratory muscle function. The decrease in these parameters can be avoided by prophylactic inspiratory muscle training, which can also prevent postoperative pulmonary complications.
Cahalin *et al.* 1997 [16]	Heart transplant	14-14/0 14 patients (12 men and 2 women) with chronic heart failure for an average of 4 years. Subjects had a mean age of 52 years.	IG = Inspiratory muscle training was performed at 20% of maximal inspiratory pressure (MIP) for 5 to 15 minutes, three times a day, for 8 weeks. CG = There wasn't.	Pre-IG MIP =51,2cmH20 Dyspnea at rest = 2 Post-IG MIP =63,5cmH2O (p = 0,001) Dyspnea at rest =1.3 (p = 0,001)	Effects of inspiratory muscle training (IMT) on ventilatory muscle strength and dyspnea in patients with chronic heart failure.

N = Total sample number; CG = Control Group l; IG = Intervention Group; IMT = Inspiratory muscle training; POPCs = Postoperative pulmonary complication; MEP = Maximum expiratory pressure; CI = Cardiac insufficiency; MIP = Maximum inspiratory pressure; FEV1 = Forced expiratory volume in the first second; FVC = Forced vital capacity

Detailing the risk of bias

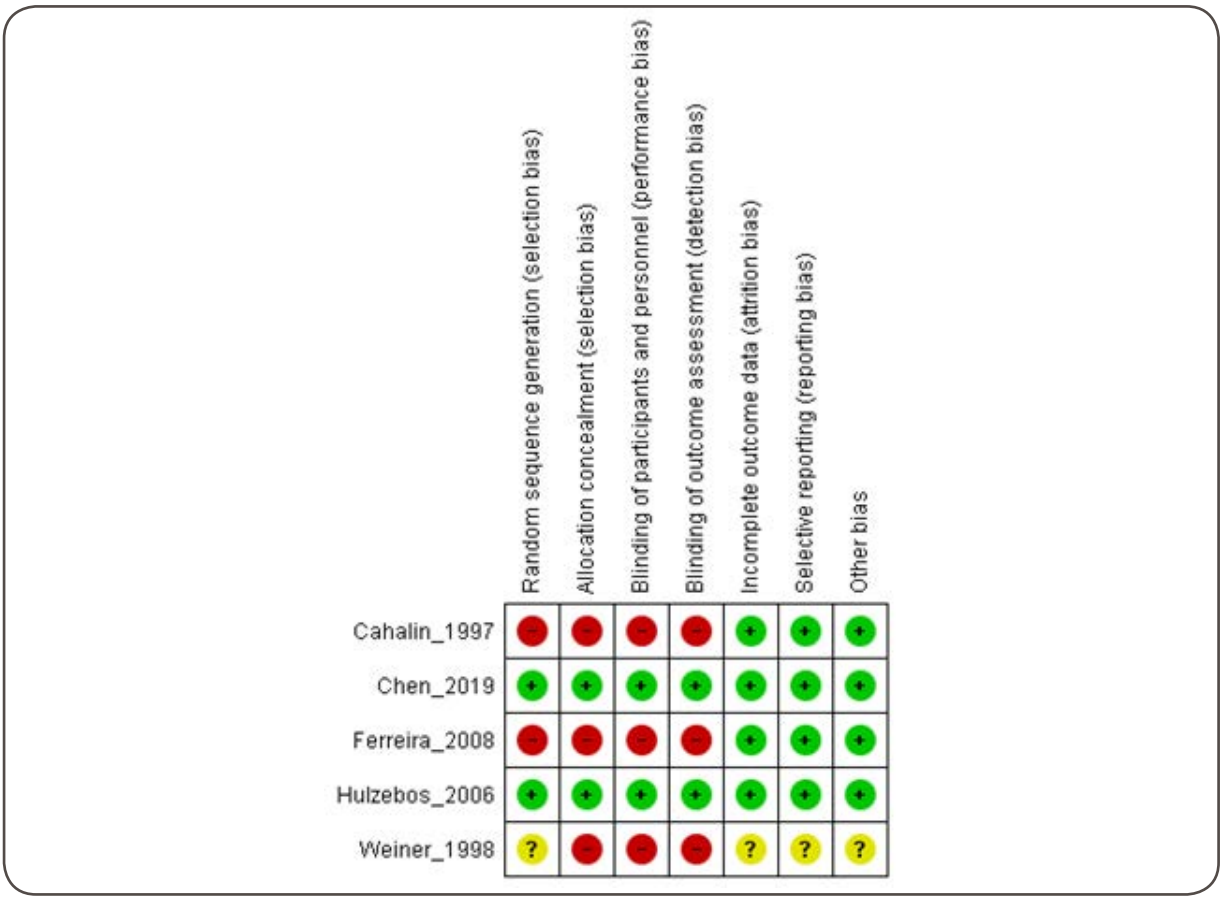

Figure 2 - Summary of the risk of bias established by the Cochrane Collaboration

The articles included were published between 1997 and 2019. Their sample size ranged from 14 to 279 adult subjects, randomized to the IMT group or the control group. The prescribing charge of MIP ranged from 15 to 60%. Five studies used 30% of the MIP in the IMT group, Chen et al. [6]; Ferreira et al. [13]; 2 published articles by Hulzebos [14,17]; one study ranged from 15 to 60% [15] and another used with 20% [16]. Regarding the control group, one study used 9% of the minimum device load [6]. A physical therapist guided deep breathing exercises without special equipment and daily walks to the limit [13], another study used instructions on deep breathing, coughing and nasal mobilization maneuvers [14]. In the following study, measurements were performed without the use of resistance [15], one of the studies had no control group [16].

The intervention period varied between 2 daily series, for 20 minutes; 3 daily sets of 10 minutes; 1 daily series of 20 minutes, 15 minutes, three times a day and 1 series of 30 minutes daily. The training protocols were daily and lasted between 5 days and 8 weeks. Table I presents the characterization of the sample, methodology, main variables, results and score on the PEDro scale [10].

Based on the results found in the studies, they were divided into 5 large groups of outcomes: MIP; FEV1; FVC; Pneumonia, duration of postoperative hospital stay and postoperative pulmonary complication.

Discussion

The aim of the present study was to analyze the effects of preoperative IMT in patients undergoing cardiac surgery. It was possible to observe an increase in MIP, VEF1 and FVC [13,16], reduction in length of stay, in addition to a decrease in the incidence of pneumonia and other postoperative pulmonary complications in the evaluated studies [6,14,15].

Of all the variables, MIP seems to be a central pillar, which also affects the others. Far from being an isolated marker of strength, it has shown considerable relevance, as seen in the study by Bessa et al. [4], where an inverse association between inspiratory muscle strength and mortality was demonstrated. It is necessary to understand how this factor can be so important, not only in the survival of patients, but also in the ability to perform activities of daily living [18], as inspiratory muscle fatigue may partially explain exercise intolerance [4].

A systematic review with meta-analysis in patients with heart failure performed by Sadek et al. [19] used some of the exercise principles and categorized the IMT in 4 ways: high intensity and moderate duration (60% MIP charge lasting 10 weeks and frequency of 3 times a week); high intensity and high duration (60% MIP load lasting 12 weeks and frequency of 6 times a week); low intensity and low duration (30-40% MIP load lasting 6-8 weeks and frequency of 7 times a week) and low intensity and high duration (30% MIP load lasting 12 weeks and frequency of 7 times a week) [19].

Still on the study of Sadek et al. [19], it was possible to verify that the high intensity and high duration training were the most effective in increasing the MIP. By way of comparison, none of the studies in our review used a load > 50% of MIP for prescription, showing that there would still be a possibility for even better results in relation to MIP. It is necessary to point out that the simple maintenance of the MIP is already considered beneficial in the postoperative period of cardiac surgery (where it is usual to fall), which in a way justifies the use of lower workloads and the achievement of positive results even without increasing inspiratory muscle strength.

In addition to MIP, other factors can be optimized by IMT and among them we can highlight the improvement in lung function [20]. In the study by Ferreira et al. [13], IMT proved to be safe, in addition to improving FVC and maximum voluntary ventilation of patients undergoing the surgical procedure. The improvement of these parameters occurs by optimizing variables such as endurance, strength, power and even increasing the strength of the expiratory muscles [7].

But how would it be possible to increase the strength of expiratory muscles through inspiratory resistance therapy? A study done in patients with bronchiectasis showed that IMT increased MEP, through a principle called "last force extension". Inspiration against resistance in IMT can increase the activation of the expiratory system, muscles responsible for the last force extension, which can result in a significant increase in MEP [21]. In our review, the study by Cahalin et al. [16] was also able

to increase MEP, showing that in this population it is also possible to extrapolate the benefits of IMT to the expiratory muscles.

Although none of the studies directly assessed coughing ability, the importance of IP and MEP for some of its phases is known. In addition, cough malfunction compromises the elimination of pathogens, inducing pulmonary infections, atelectasis and increased costs and length of hospital stay [22]. According to this line of reasoning, the works by Hulzebos et al. [14] and Weiner et al. [15] found a reduction in complications and consequently in the length of hospital stay in patients who underwent IMT.

Some factors should be highlighted, and one of them is that although pulmonary function has increased, interestingly, the study by Ferreira et al. [13] did not change MIP. Studies need to be more specific regarding the principles of physical exercise, repetitions, intensity, load progression [23,24].

Certain goals can be achieved with prescription adjustments varying within a range. Strength training is typically used with a higher load and fewer repetitions, with endurance goals done in reverse [25,26]. The outcomes evaluated in this study can benefit from both types of training, remembering the importance of individualized prescription and even that a mixed training can be used. It was not clear in the studies evaluated whether reassessments were carried out between sessions and whether the training load could be increased. The time of use of the technique was also very heterogeneous, varying between 5 days, as in the study by Chen et al. [6] and 8 weeks in the study by Cahalin et al. [16].

Thus, IMT has beneficial effects on lung function and length of hospital stay, although its prescription still needs to be individualized. It is necessary to define more clearly the principles of physical exercise and endurance, as well as the benefits resulting from them.

Conclusion

The results of this systematic review indicate that IMT is beneficial in the prevention of pulmonary complications such as pneumonia, increase in MIP, FEV1 and VC, in addition to reducing the length of hospital stay, when performed in the preoperative period of cardiac surgery. Despite the findings mentioned here, further research needs to be carried out, detailing the principles of physical exercise, endurance and training periodization.

Potential conflict of interest
No conflict of interest.

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Authors' contribution
Research conception and design: Lima AS, Oliveira ACC, Silva CMS; **Obtaining data:** Lima AS, Oliveira ACC; **Data analysis and interpretation:** Silva CMC, Souza SC, Gomes VA; **Writing of the manuscript:** Lima AS, Oliveira AC; **Critical review of the manuscript for important intellectual content:** Silva CMS, Souza SC, Gomes VA.

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