Efecto del entrenamiento muscular inspiratorio en pacientes sometidos a cirugía torácica y abdominal superior: una revisión integradora

Effect of inspiratory muscle training in patients undergoing thoracic and high abdominal surgery: an integrative review

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Abstract

Introduction: Thoracic and high abdominal surgeries can result in significant respiratory complications, including decreased respiratory muscle strength, reduced lung volumes, and impaired functional capacity. Inspiratory muscle training has been proposed as a strategy to mitigate these impairments; however, evidence regarding its effectiveness in the postoperative setting remains inconsistent.
Objective: To describe the effects of inspiratory muscle training on respiratory muscle strength in patients following thoracic and upper abdominal surgery.
Methodology: An integrative review was conducted, including controlled and uncontrolled clinical trials published between 2013 and 2023 in English or Portuguese. Searches were performed in the PubMed, Lilacs, and Scielo databases. Three independent researchers selected and analyzed the studies, and methodological quality was assessed using the PEDro scale.
Results: Of the twenty-eight identified trials, seven met the eligibility criteria and were analyzed. According to the PEDro scale, the studies exhibited methodological quality ranging from fair to excellent. Most studies included pre-obese individuals under 40 years of age who had undergone cardiac or thoracic surgery. The intervention duration varied, ranging from the immediate postoperative period to 12 months.
Conclusions: Inspiratory muscle training can enhance inspiratory muscle strength in hospitalized patients following thoracic and high abdominal surgeries. Thus, this intervention can be integrated into respiratory physiotherapy to prevent respiratory complications and reduce hospitalization duration, morbidity, and mortality. Nevertheless, standardized protocols and further research with homogeneous methodologies are needed to confirm the benefits of inspiratory muscle training and establish consistent practices.

Keywords

Breathing exercises; myocardial revascularization; review; thoracic surgery.

Resumen

Introducción: Las cirugías torácicas mayores y abdominales superiores pueden provocar complicaciones respiratorias significativas, como disminución de la fuerza de los músculos respiratorios, reducción de los volúmenes pulmonares y deterioro de la capacidad funcional. El entrenamiento de los músculos inspiratorios se ha propuesto como una estrategia para mitigar estas alteraciones; sin embargo, la evidencia sobre su efectividad en el contexto postoperatorio sigue siendo inconclusa.
Objetivo: Describir los efectos del entrenamiento de los músculos inspiratorios sobre la fuerza muscular respiratoria en pacientes sometidos a cirugía torácica y abdominal superior.
Metodología: Revisión integrativa que incluyó ensayos clínicos controlados y no controlados publicados entre 2013 y 2023 en inglés o portugués. Se realizaron búsquedas en las bases de datos PubMed, Lilacs y Scielo. Tres investigadores independientes seleccionaron y analizaron los estudios, y la calidad metodológica fue evaluada mediante la escala PEDro.
Resultados: De los veintiocho ensayos identificados, siete cumplieron los criterios de elegibilidad y fueron analizados. Según la escala PEDro, la calidad metodológica de los estudios varió de regular a excelente. La mayoría de los estudios incluyeron individuos preobesos menores de 40 años que habían sido sometidos a cirugía cardíaca o torácica. La duración de la intervención varió desde el período postoperatorio inmediato hasta 12 meses.
Conclusiones: El entrenamiento de los músculos inspiratorios puede mejorar la fuerza muscular inspiratoria en pacientes hospitalizados después de cirugías torácicas mayores y abdominales superiores. Por lo tanto, esta intervención puede integrarse en la fisioterapia respiratoria para prevenir complicaciones respiratorias y reducir la duración de la hospitalización, la morbilidad y la mortalidad. No obstante, se requiere la estandarización de protocolos y la realización de estudios adicionales con metodologías homogéneas para confirmar los beneficios del entrenamiento de los músculos inspiratorios y establecer prácticas clínicas consistentes.

Palabras clave

Ejercicios respiratorios; revascularización miocárdica; revisión; cirugía torácica.

Introduction

Thoracic and high abdominal surgeries are considered complex procedures capable of triggering various complications during hospitalization, such as biomechanical compromise, cardiovascular system impairment, neurological system impairment, and especially respiratory system impairment. These impairments contribute to functional decline and consequent prolongation of hospital stay, resulting in increased morbidity and mortality and decreased quality of life (Laizo et al., 2010; Cordeiro et al., 2016; Cordeiro et al., 2021; Huang et al., 2022; Almeida et al., 2024).

Regarding respiratory complications, acute respiratory distress syndrome, bronchospasm, pneumonia, atelectasis, pleural effusion, pneumothorax, infections, and respiratory failure are notable (Shakouri et al., 2015; Cordeiro et al., 2021). These conditions can lead to dysfunction and/or decrease in respiratory muscle strength, which in turn is associated with decreased lung volumes, alteration in ventilation/perfusion ratio, and reduction in cardiorespiratory and functional capacity (Huang et al., 2022; De Araújo-Filho et al., 2017; Cordeiro et al., 2016; Cordeiro et al., 2021).

In this context, strategies should be implemented to restore respiratory muscle strength and functional capacity. Among these, inspiratory muscle training (IMT) is an important resource in respiratory physiotherapy. This training strengthens the respiratory muscles, aids in airway clearance by improving inspiratory and expiratory pressures, thereby enhancing cough efficacy, promotes better thoracic wall geometry, and increases vital capacity (Enright et al., 2004; Oliveira et al., 2009; Shakouri et al., 2015; Basha et al., 2024; Aktan et al., 2025).

Despite the well-documented impact of thoracic and high abdominal surgeries on respiratory function, particularly regarding inspiratory muscle dysfunction and the subsequent reduction in lung volumes and capacities, evidence on the role of IMT in mitigating these impairments remains scarce. While some studies suggest potential benefits (Kodric et al., 2013; Miozzo et al., 2018; Huang et al., 2022), findings are inconsistent, and no consensus exists on its effectiveness in the postoperative setting (Rocha et al., 2018; Cordeiro et al., 2020). Furthermore, no review has comprehensively examined the extent to which IMT influences pulmonary expansion and postoperative complications, which are critical factors in patient recovery and hospital outcomes.

Given this gap in the literature, the present study aims to synthesize available evidence on the effects of IMT on respiratory muscle strength in patients undergoing thoracic and high abdominal surgery, with a particular focus on its impact on pulmonary expansibility and potential surgical complications.

Method

This is an integrative review with a qualitative approach. Evidence was searched in the PubMed/MEDLINE, Lilacs, and Scielo databases. Terminologies registered in the Health Sciences Descriptors (DeCS) created by the Virtual Health Library, developed from the Medical Subject Headings (MeSH) of the U.S. National Library of Medicine, were used, allowing the use of common terminology in Portuguese, English, and Spanish. The search strategy used in all databases was: ("breathing exercises" OR "respiratory therapy") AND ("vital capacity") AND ("muscle strength" OR "respiratory muscles") AND (surgery).

The search and selection of articles were conducted between January and August 2023. Controlled and uncontrolled clinical trials published in the last 10 years (from 2013 to 2023) in English or Portuguese investigating the effects of IMT on the strength of respiratory muscles in individuals in the postoperative period of thoracic or high abdominal surgery were included. Articles should assess respiratory muscle strength through maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP). Studies were excluded if they were unavailable in full text, involved individuals under 18 years of age, addressed surgeries other than thoracic or high abdominal, or did not include IMT intervention.

Three independent researchers participated in the four stages of the review: 1) literature search, 2) duplicate analysis, 3) title and abstract screening, and 4) full-text reading of each article. In the third and fourth stages, each researcher classified the articles in a binary manner: zero (0) for articles that did not meet the inclusion criteria or fell under any exclusion criteria and one (1) for articles relevant to the review topic. Articles that received a score of one (1) from all three researchers progressed to the next stage or were immediately included if they were already in the 4th stage. Discrepancies were resolved among the authors.

The PEDro scale was employed to assess the methodological quality of the included studies. This scale is widely recognized for evaluating clinical trials and classifies studies based on criteria such as randomization, blinding, and data analysis, assigning a score that ranges from 0 to 10 (Kamper et al., 2015; Moseley et al., 2002; Moseley et al., 2020). A higher score indicates better methodological quality of the study. We applied the following classification: studies scoring below four were considered to have low methodological quality, those scoring between 4 and 5 were deemed to have fair methodological quality, studies scoring between 6 and 8 were classified as having good methodological quality, and articles scoring between 9 and 10 were rated as excellent (Cashin & McAuley, 2020).

Results

Figure 1 presents the flowchart of the identification and selection of articles included in the present review, following the PRISMA flowchart (Liberati et al., 2009). In total, seven articles were included, with the main results described in Table 1. According to the PEDro scale, the studies showed methodological quality ranging from fair to excellent (Table 2).

Figure 1. Flowchart of identified, excluded, and selected articles.

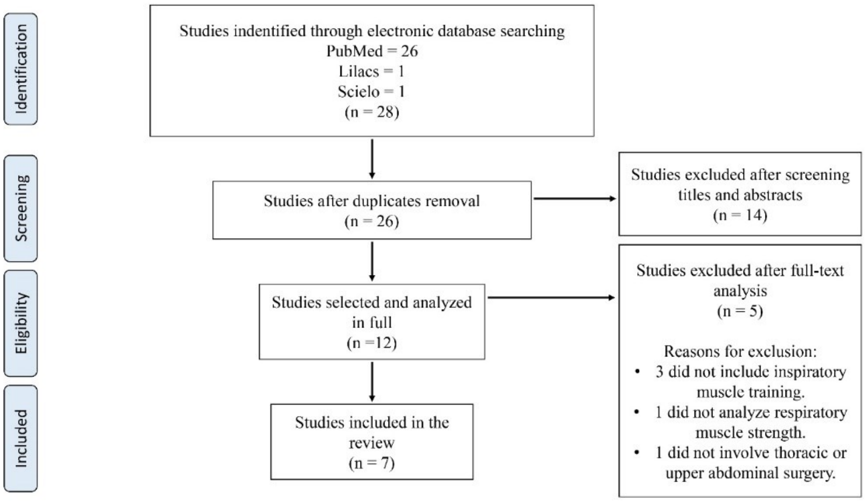

Table 1. Characteristics by author, sample, exercise protocol, and main results of included studies, 2013 to 2023.

AUTHOR/YEAR	GROUPS	EXERCISE PROTOCOL	MAIN RESULTS	OTHER RESULTS
Huang *et al*., 2022	Patients undergoing high abdominal surgery (n=28) Control Group (CLT): n=15 (11 males; 4 females). IMT Group: n=13 (7 males; 6 females). Age: 44.8 ± 14.2 years (CLT) 46.4 ± 12.9 years (IMT) BMI: 22.7 kg/m² (IMT)	IMT Group: IMT. CLT Group: No intervention. • Duration: 7 weeks; starting 3 weeks before surgery and ending in the 4th postoperative week. • Frequency: - Preoperative: Twice daily; 5 times a week, for at least 2 weeks; totaling 10 sessions. - Postoperative: Twice daily; 5 times a week, until hospital discharge. • Intensity: - Preoperative: IMT was performed at a moderate to high intensity (50% of MIP) according to the patient's baseline level; intensity was increased by 5-10% per week. - Postoperative: IMT threshold applied immediately after endotracheal extubation; then IMT intensity was defined based on measurement of MIP after surgery. • Each session lasted 25 to 30 minutes.	Preoperative: Significant increase in MIP in the IMT group compared to the 3rd preoperative week and two days before surgery; with a significant difference between the CLT and IMT groups two days before surgery. A similar degree of variability in MEP for both groups. Postoperative: Significant decrease in MIP and MEP compared to the preoperative period; Significant increase in MIP for the IMT group compared to baseline values.	Higher complication rate in the CLT group compared to the IMT group; however, there was no difference in hospitalization time. IMT did not affect lung function but prevented the decrease in cand mitigated the decline in FEV1. Decrease in cardiopulmonary capacity in the postoperative period in the CLT group. Preservation of diaphragmatic excursion capacity in the IMT group; decline in diaphragmatic excursion in the CLT group.
Hegazy *et al*., 2021	Patients undergoing mitral valve replacement surgery (n=100) Control Group (CG): n=50 (25 males; 25 females).	CG: Postoperative physiotherapy routine protocol. EG: Postoperative physiotherapy routine protocol combined with Threshold IMT. • Duration: 8 weeks • Frequency: Daily, twice a day until hospital	There was a pronounced reduction in MIP in both groups after surgery (before the start of the intervention protocol). Gradual improve-	There was a pronounced reduction in pulmonary function parameters in both groups after surgery. The EG showed better pulmonary

	Experimental Group (EG): n=50 (26 males; 24 females). Age: 38.3 ± 3.29 years (CG) 39 ± 4.28 years (EG) BMI: 28.23 kg/m² (CG) 27.32 kg/m² (EG)	discharge; and 4 times per week (in the outpatient cardiopulmonary rehabilitation unit) after hospital discharge until the 8th postoperative week. • Intensity: Started at 40% of the preoperative MIP, gradually increasing by 5%-10% each week, reaching 80% of the preoperative MIP by the end of the 8th postoperative week. • 20-30 minutes per session; 6 sets of five deep breaths against the IMT device; 1–2-minute interval between sets.	ments in MIP were observed after the intervention over time in both groups. The EG showed higher MIP compared to the CG at three-time points: hospital discharge, after 4 weeks post-surgery, and after 8 weeks post-surgery.	function compared to the CG at three-time points: hospital discharge, after 4 weeks post-surgery, after 8 weeks post-surgery, and after 6 months post-surgery. There was a significant difference in functional capacity (6-minute walk test) between the EG and CG, with better functional capacity in the EG.

Table 1. Characteristics by author, sample, exercise protocol, and main results of included studies, 2013 to 2023 (*Continued*).

AUTHOR/YEAR	GROUPS	EXERCISE PROTOCOL	MAIN RESULTS	OTHER RESULTS
Cordeiro *et al*., 2020	Patients undergoing coronary artery bypass graft surgery (n=42) Conventional IMT Group (IMT-C): n=21 (13 males; 8 females). Anaerobic Threshold-based IMT Group (IMT-AT): n=21 (14 males; 7 females). Age: 62 ± 10 years (IMT-C) 61 ± 9.6 years (IMT-AT) BMI: 27 ± 3.9 kg/m² (IMT-C) 27 ± 3.2 kg/m² (IMT-AT)	Both groups underwent IMT. • Duration: Indefinite - started on the first day after the surgical procedure and ended at hospital discharge. • Frequency: Twice a day until hospital discharge. • Intensity: - IMT-C: 3 sets of 15 repetitions at 40% of MIP. - IMT-AT: 3 sets of 15 repetitions with load prescribed according to the glycemic threshold found in the maximum progressive test* conducted to assess inspiratory muscle endurance. *Maximum progressive test using the PowerBreath Knectic Series® Device: 10 stages of 15 repetitions with increasing load (10% per stage), starting at 10% of the pre-surgery MIP value; at the end of each stage, a 2-minute interval was allowed, and capillary glycemia was assessed; the test was stopped when the individuals were no longer able to overcome the load imposed by the device or expressed the impossibility of continuing with the test. IMT was performed with a load corresponding to the lowest glycemic value found in the test; the load measurement was repeated every four days.	The load used for IMT in the IMT-AT group was lower than the load used by the IMT-C group. There was a reduction in MIP in both groups when comparing values at hospital discharge to preoperative values, but this decrease was greater in the IMT-C group. There was also a reduction in MEP in both groups when comparing values at hospital discharge to preoperative values.	There was a reduction in lung function in both groups at hospital discharge compared to preoperative values. There was a reduction in submaximal functional capacity in both groups when comparing hospital discharge to preoperative values; the IMT-C group showed a greater decrease in distance walked. The IMT-AT group had a shorter hospital stay compared to the IMT-C group.
Pazzianotto-Forti *et al*., 2019	Patients undergoing Roux-en-Y gastric bypass surgery via laparotomy (bariatric surgery) (n=40) Linear Load Pressure Group (LLP): n=20 (only females). Non-Linear Load Pressure Group (NLP): n=20 (only females). Age: 39.35 ± 6.33 years (LLP) 37.4 ± 8.48 years (NLP) BMI: 45.64 ± 3.94 kg/m² (LLP) 45.16 ± 3.9 kg/m² (NLP)	Both groups underwent conventional respiratory physiotherapy and IMT. NLP: Conventional respiratory physiotherapy combined with IMT using non-linear pressure load (DHD 22-7500 IMT Device). • Duration: During hospitalization in the immediate postoperative period and the first postoperative day. • Frequency: - LLP and NLP: Conventional respiratory physiotherapy once in the immediate postoperative period and twice on the first postoperative day; and IMT with linear pressure load (LLP group; PowerBreath equipment) and non-linear pressure load (NLP group; DHD 22-7500 IMT Device) twice in the immediate postoperative period immediately after waking up from sedation and five times on the first postoperative day, with intervals of 3 hours. • Intensity: - Conventional respiratory physiotherapy: 1 set of 10 repetitions for each exercise + exercises for deep vein thrombosis prevention and ambulation. - IMT LLP: 40% of the preoperative PImax; 6 sets of 15 repetitions with rest intervals of 30 to 60 seconds between sets. - IMT NLP: Resistance was standardized, and all participants used the 2mm diameter red orifice; they performed explosive, fast, and intense inspirations and normal expirations in 6 sets of 15 breaths with rest intervals of 30 to 60 seconds between sets.	There was no difference in the strength and endurance of the inspiratory muscles, measured by nasal inspiratory pressure and PImax, between the LLP and NLP groups, both in the preoperative and postoperative periods. Significant reductions in nasal inspiratory pressure and the power and volume of PImax were observed in both groups in the postoperative period.	15% of individuals in the LLP group and 25% of individuals in the NLP group presented atelectasis in the postoperative period, however, there was no significant difference.

Table 1. Characteristics by author, sample, exercise protocol, and main results of included studies, 2013 to 2023 (*Continued*).

AUTHOR/YEAR	GROUPS	EXERCISE PROTOCOL	MAIN RESULTS	OTHER RESULTS
Rocha *et al*., 2018	Patients undergoing bariatric surgery (n=45) Positive Pressure Group (PPG): n=23 (only females).	PPG: Conventional respiratory physiotherapy and positive pressure at two levels (Bi-level Positive Airway Pressure - BiPAP). ILG: Conventional respiratory physiotherapy and IMT with linear pressure load (PowerBreath). • Duration: During hospitalization in the	Significant reduction in nasal inspiratory pressure and MIP and their components (volume and power) in	There was a significant reduction in the variables FVC and FEV1 of lung function in both groups postoperatively but without significant

	Inspiratory Load Group (ILG): n=22 (only females). Age: 38.2 ± 9.40 years (PPG) 36.9 ± 5.92 years (ILG) BMI: 46.94 ± 4.54 kg/m^2 (PPG) 44.66 ± 4.06 kg/m^2 (ILG)	immediate postoperative period and the first postoperative day. • Frequency: - PPG: Conventional respiratory physiotherapy once in the immediate postoperative period and twice on the first postoperative day; and BiPAP twice a day in the immediate postoperative period and after 4 hours, and three times a day on the first postoperative day, with a 6-hour interval between sessions; each BiPAP session lasted for 1 hour. - ILG: Conventional respiratory physiotherapy once in the immediate postoperative period and twice on the first postoperative day; and IMT with linear pressure load twice in the immediate postoperative period and three times on the first postoperative day, with a 6-hour interval between sessions. • Intensity: - PPG: BiPAP with initial inspiratory positive airway pressure (IPAP) set to 12 cmH2O and adjusted according to tolerance, maintaining the respiratory rate below 30 breaths per minute and tidal volume around 8-10 ml/kg; expiratory positive airway pressure (EPAP) was set to 8 cmH2O, both according to Brazilian Mechanical Ventilation recommendations. - ILG: 40% of the preoperative MIP; 6 sets of 15 repetitions with rest intervals of 30-60 seconds between sets.	the postoperative period in the PPG. Significant reduction in the volume of MIP in the postoperative period in the ILG and maintenance of MIP and power. A significant difference between the groups in nasal inspiratory pressure, demonstrat-ing the superiority of the ILG in maintaining this value compared to the PPG.	difference between the groups. The prevalence of atelectasis was 5% in both groups with no significant difference between them.
Miozzo *et al.*, 2018	Patients undergoing coronary artery bypass graft surgery (n=18). Aerobic Exercise Group (AEG): n=9 Aerobic Exercise and IMT Group (AEG+IMT): n=9 Age: 57.4 ± 8.54 years (AEG) 57.6 ± 7.9 years (AEG+IMT) BMI: 28.1 ± 2.79 kg/m^2 (AEG) 25.4 ± 3.02 kg/m^2 (AEG+IMT)	AEG+IMT: Aerobic exercise combined with high-intensity IMT using a linear pressure loading device (PowerBreath Plus Resistance®). AEG: Aerobic exercise. • Duration: Twelve weeks • Frequency: Not specified • Intensity: - AEG+IMT: - IMT - 05 sets of 10 repetitions until the 8th week with progression of the number of sets (1 per week) and repetitions (10 to 12) from the 8th to the 12th week; adjusting the overload weekly by reevaluation of MIP, starting with 50% of MIP in the first 2 weeks, 60% of MIP in the 3rd and 4th weeks, 70% of MIP in the 5th and 6th weeks, and 80% of MIP from the 7th week until the end of the protocol. - Aerobic exercises: an average of 40 minutes of aerobic training divided into 3 phases – Phase 1: 12 sessions with 50% to 60% of peak heart rate reserve (HRR); Phase 2: 12 sessions with 60% to 70% of HRR; Phase 3: 12 sessions with 70% to 80% of HRR.	There was a significant increase in MIP in both groups over time up to the 24th session. The AEG+IMT group started with lower MIP values and reached higher values, with the difference between pre- and post-values approximately 20% in the AEG group and 40% in the AEG+IMT group, meaning a 20% difference between the groups. Significant differences in MEP within groups were only observed at the 12th, 24th, and 36th sessions when compared to the baseline.	There was no significant difference in functional capacity (6-minute walk test) at any of the four-time points when comparing the groups. Both groups showed improvement in maximum oxygen consumption after aerobic training. There was an intragroup difference in peripheral muscle strength in the sit-to-stand test, with an increase at the 12th, 24th, and 36th time points.

Table 1. Characteristics by author, sample, exercise protocol, and main results of included studies, 2013 to 2023 (*Continued*).

AUTHOR/YEAR	GROUPS	EXERCISE PROTOCOL	MAIN RESULTS	OTHER RESULTS
Kodric *et al.*, 2013	Patients undergoing major cardiac surgery (coronary artery bypass grafting, valve replacement, or both) (n=52) Training Group (IMT Group): n=36 (6 females; 30 males) Control Group (CG): n=16 (5 females; 11 males) Age: 66.9 ± 9.2 years (IMT Group) 68.6 ± 9.0 years (CG) BMI: Not reported	IMT group: IMT with a variable pressure device (Threshold-IMT). GC: IMT with a sham device. • Duration: 12 months starting from the 4th postoperative week. • Frequency: Daily. • Intensity: - IMT group: Inspiratory load varied across the 4 phases of each cycle based on the percentage of MIP: 5 minutes of inspiratory load set at 30% of MIP followed by 2 minutes of deep, slow breathing; 5 minutes of inspiratory load set at 70% of MIP followed by 2 minutes of deep, slow breathing; 5 minutes of inspiratory load set at 15% of MIP followed by 2 minutes of deep, slow breathing; 5 minutes of inspiratory load set at 80% of MIP followed by 2 minutes of deep, slow breathing. MIP was reassessed at 3 and 6 months, and the device was recalibrated accordingly. - GC: Followed the same schedule with a sham device that provided no training.	Significant improve-ment in MIP was observed in the G- IMT group, but there was no improvement in the GC. There was a significant increase in MEP in both groups.	Significant improvement was observed in the variable FEV1 of pulmonary function in the IMT group. There were no significant differences between the groups in the final assessment of pulmonary function. Most patients in the IMT group showed partial or complete improvement in diaphragm motility, while the majority of the GC did not show improvement. Significant improvement in dyspnea and ADLs after 6 and 12 months in the

IMT group compared to the GC.

Legend: ADLs: Activities of Daily Living; AEG: Aerobic Exercise Group; AEG+IMT: Aerobic Exercise and Inspiratory Muscle Training Group; AVDs: Activities of Daily Living; BIPAP: Bilevel Positive Airway Pressure; BMI: body mass index; CG/CLT: Control Group; CVL: Slow Vital Capacity; EG: Experimental Group; EPAP: Expiratory Positive Airway Pressure; FEV1: Forced Expiratory Volume in one second; FR: Respiratory Rate; FVC: Forced Vital Capacity; GC: Control Group; HRR: heart rate reserve; ILG: Inspiratory Load Group; IMT: Inspiratory Muscle Training; IMT-AT: Anaerobic Threshold-based Inspiratory Muscle Training; IMT-C: Conventional Inspiratory Muscle Training; IPAP: Inspiratory Positive Airway Pressure; LLP: Linear Load Pressure; MEP: Maximum Expiratory Pressure; MIP/PImax: Maximum Inspiratory Pressure; NLP: Non-Linear Load Pressure; PPG: Positive Pressure Group. Source: authors' elaboration, 2023.

Table 2. Methodological quality for the included trials.

	Methodological quality (PEDro Scale)												
First author	Eligibility criteria	Random Assignment	Allocation concealment	Initial comparability	Participant Blinding	Provider Blinding	Blinding of Outcome Assessors	Retention	Analysis by intention to treat	Comparison between groups	Variability of key outcome provided	Total Score	Quality of study
Cordeiro *et al.*, 2020	Y	Y	Y	Y	N	N	N	N	N	Y	Y	5	FAIR
Hegazy *et al.*, 2021	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	7	GOOD
Huang *et al.*, 2022	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6	GOOD
Kodric *et al.*, 2013	Y	Y	Y	Y	N	N	Y	N	N	Y	Y	6	GOOD
Miozzo et al., 2018	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6	GOOD
Pazzianotto-Forti et al., 2019	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	9	EXCELLENT
Rocha *et al.*, 2018	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	9	EXCELLENT

Abbreviations: N, no; Y, yes.

Population

The number of individuals studied ranged from 18 (Miozzo et al., 2018) to 100 (Hegazy et al., 2021). The average age varied between 40 and 60 years (Miozzo et al., 2018; Huang et al., 2022), over 60 years (Kodric et al., 2013; Cordeiro et al., 2020), and below 40 years (Rocha et al., 2018; Pazzianotto-Forti et al., 2019; Hegazy et al., 2021).

The body mass index varied among three categories according to the World Health Organization (2000): normal weight (Huang et al., 2022), pre-obesity (Miozzo et al., 2018; Cordeiro et al., 2020; Hegazy et al., 2021; Huang et al., 2022), and obesity (Rocha et al., 2018; Pazzianotto-Forti et al., 2019), and one article did not provide this information (Kodric et al., 2013). The studies included individuals who underwent cardiac/thoracic surgery (myocardial revascularization, valve replacement, or both) (Kodric et al., 2013; Miozzo et al., 2018; Cordeiro et al., 2020; Hegazy et al., 2021) and individuals undergoing high abdominal surgery (liver transplant recipient and donor and bariatric surgery) (Rocha et al., 2018; Pazzianotto-Forti et al., 2019; Huang et al., 2022).

Intervention

IMT was present in all articles, as it is a mandatory criterion of the present study, but with the use of different devices. The linear pressure device, Threshold-IMT, was used in two studies (Kodric et al., 2013; Hegazy et al., 2021), and the PowerBreath device in four (Miozzo et al., 2018; Rocha et al., 2018; Pazzianotto-Forti et al., 2019; Cordeiro et al., 2020), while one study addressed IMT using a non-linear pressure device, DHD 22-7500 (Pazzianotto-Forti et al., 2019). In turn, one study used positive pressure at two levels as an intervention (Rocha et al., 2018), and another study did not specify the method of intervention performed (Huang et al., 2022).

Regarding the intensity of the training, all studies used MIP, assessed through manovacuometry testing, to prescribe the load used in IMT, ranging from 30% (Kodric et al., 2013) to 80% (Kodric et al., 2013; Miozzo et al., 2018; Hegazy et al., 2021) of measured MIP. However, one study prescribed a load of IMT for one of the groups using the glycemic threshold found in a maximal progressive test (Cordeiro et al., 2020). Additionally, high-intensity aerobic training was associated with IMT in one study (Miozzo et al., 2018), and conventional respiratory physiotherapy was associated with IMT in two studies (Rocha et al., 2018; Pazzianotto-Forti et al., 2019; Hegazy et al., 2021).

Regarding the frequency of IMT, one study did not specify the daily frequency (Miozzo et al., 2018), while in the other studies, the frequency varied from once a day (Kodric et al., 2013) to five times a day (Pazzianotto-Forti et al., 2019). Weekly frequency was addressed only in two studies (Hegazy et al., 2021; Huang et al., 2022).

Finally, regarding the training duration, two studies conducted the IMT intervention only in the immediate postoperative period and on the first day of postoperative (Rocha et al., 2018; Pazzianotto-Forti et al., 2019), one study was conducted for an indefinite period, according to the hospitalization period (Cordeiro et al., 2020), three studies conducted IMT between seven and twelve weeks (Miozzo et al., 2018; Hegazy et al., 2021; Huang et al., 2022), and one study extended the training time for up to 12 months (Kodric et al., 2013).

Research outcome

Regarding the outcomes of IMT in patients undergoing thoracic and upper abdominal surgeries, two studies initiated IMT in the preoperative period and observed that, regardless of the device used, the groups that underwent IMT showed an increase in MIP before surgery (Pazzianotto-Forti et al., 2019; Huang et al., 2022). On the other hand, two studies analyzed the effects of these surgeries on MIP, reflecting the strength of the inspiratory muscles, comparing the preoperative period to the immediate postoperative period, i.e., before the start of post-surgery IMT, and found a significant decrease in MIP immediately after the surgical procedure, even when preoperative IMT was performed (Hegazy et al., 2021; Huang et al., 2022).

Conversely, five studies analyzed the effect of IMT by comparing preoperative and postoperative MIP after several IMT sessions. Of these, three studies found a significant improvement in MIP (Kodric et al., 2013; Miozzo et al., 2018; Huang et al., 2022), while two observed maintenance and/or decrease in MIP (Rocha et al., 2018; Cordeiro et al., 2020).

Additionally, a study that performed IMT with different pressure loading devices, linear and nonlinear, compared the effects on MIP in both groups in the postoperative period and observed no difference between them, indicating that the device did not interfere with the strengthening of the inspiratory muscles (Pazzianotto-Forti et al., 2019). However, the same was not observed when different physiotherapeutic approaches such as aerobic exercises (Miozzo et al., 2018), positive pressure (Rocha et al., 2018), and conventional physiotherapy (Hegazy et al., 2021) were performed. In these cases, IMT I was responsible for improving MIP or nasal inspiratory pressure in two studies (Rocha et al., 2018; Hegazy et al., 2021), while one study found no difference between the group that underwent IMT and the proposed physiotherapeutic approach (Miozzo et al., 2018).

Discussion

This review aimed to synthesize the available evidence on the effects of IMT on respiratory muscle strength in patients undergoing thoracic and upper abdominal surgeries. We found that IMT, particularly using threshold pressure training devices, may be beneficial during hospitalization by promoting inspiratory muscle strength in these patients. Most included studies demonstrated good methodological quality; however, variations in protocols and study populations influence the results and hinder more definitive conclusions for clinical practice, highlighting the need for further research on this topic.

It is worth noting that respiratory muscles can be classified as inspiratory and expiratory. During inspiration, the diaphragm and external intercostal muscles contract, pulling the lower surfaces of the lungs downward and elevating the thoracic cage, respectively. During expiration, the diaphragm and external intercostal muscles relax. However, during vigorous breathing, accessory muscles classified as aiding inspiration (such as sternocleidomastoids, anterior serratus, and scalene) and expiration (abdominal musculature and internal intercostals) will participate (Sarmento et al., 2009; Hall & Hall, 2011; Machado, 2012).

More specifically, the types of muscle fibers present in respiratory muscles, predominantly type I fibers, followed by type IIa and IIb fibers, must be considered for a good physiotherapeutic approach when the goal is muscle strength gain. Type I fibers are related to low-intensity tonic work, have slow contraction time, and greater fatigue resistance. In contrast, type II fibers are considered high-intensity, have a fast contraction, and are less fatigue-resistant (Machado, 2012).

Some studies suggest that IMT with low loads can influence the optimization of type I and IIa fibers. In contrast, loads above 50% of maximal force may cause the diaphragm muscle to work beyond its endurance and strength characteristics, preventing beneficial muscle adaptations (Dot et al., 2017; Miozzo et al., 2018; Cordeiro et al., 2020). Conversely, other studies suggest that the safest method for adjusting IMT intensity would be to use a load at 40% of MIP, measured previously through a manovacuometry test, and it can reach up to 80% of MIP (Gomes et al., 2017; Kendall et al., 2018).

In the present review, we observed that the loads used for IMT were prescribed based on MIP, measured before the surgeries, ranging from around 30% (Kodric et al., 2013) to 80% (Kodric et al., 2013; Miozzo et al., 2018; Hegazy et al., 2021) of MIP, thus covering loads from light to high intensity. Among the five studies that performed IMT and analyzed its effects on inspiratory muscle strength after thoracic and high abdominal surgeries, three studies found a significant improvement in MIP (Kodric et al., 2013; Miozzo et al., 2018; Huang et al., 2022), while two observed maintenance and decrease in MIP (Rocha et al., 2018; Cordeiro et al., 2020). The variation in the devices and training intensities (from 30% to 80% of the PImáx) can lead to divergent responses. The heterogeneity in the IMT protocols analyzed may have significantly contributed to the variability in the observed results. Additionally, differences in age and body mass index across populations could influence training responses. Kodric et al. (2013) and Cordeiro et al. (2020) studied patients over 60 years of age, while Rocha et al. (2018) and Pazzianotto-Forti et al. (2019) focused on younger populations. This age difference may impact the ability of inspiratory muscles to adapt to training, reflecting what is described in the literature on senescence. Senescence, characterized by muscle strength decline of 20% to 40% in individuals aged 70 to 80 and up to 50% in nonagenarians, is associated with increased body fat and sarcopenia, which can lead to functional disabilities (Garcia, 2008; Pícoli, 2011).

Due to these variations, it is not easy to establish a uniform program because of numerous differences (Brown & Kilding, 2011; Galleguillos et al., 2024). Therefore, it is essential to consider the type of exercise, intensity, and frequency when developing interventions, ensuring the protocol addresses morphological, cardiorespiratory, muscular, motor, and metabolic factors.

The frequency of IMT also varied widely, ranging from once a day (Kodric et al., 2013) to up to five times a day (Pazzianotto-Forti et al., 2019), with weekly frequency addressed only in two studies (Hegazy et al., 2021; Huang et al., 2022). The duration of training periods also differed considerably, with some protocols depending on the length of hospital stay (Rocha et al., 2018; Pazzianotto-Forti et al., 2019; Cordeiro et al., 2020), while others lasted from seven to twelve weeks (Miozzo et al., 2018; Hegazy et al., 2021; Huang et al., 2022), and even up to 12 months (Kodric et al., 2013).

In addition, in the selected studies, the association of IMT with other types of interventions, such as high-intensity aerobic training (Miozzo et al., 2018) and conventional respiratory physiotherapy (Rocha et al., 2018; Pazzianotto-Forti et al., 2019; Hegazy et al., 2021) was also found. These factors, as mentioned earlier, may have influenced the presented results.

These findings show that there needs to be standardization in the prescription of protocols to promote the strengthening of inspiratory muscles, which may have influenced the divergent results. It is necessary to consider that physical fitness is composed of various characteristics related to cardiorespiratory fitness, muscle strength and endurance, flexibility, and body composition (Theander et al., 2009; Hamad et al., 2024; Donate et al., 2023; Suryadi et al., 2024). Furthermore, adaptive responses are related to variables found in physical exercise such as load imposed, number of repetitions, sets, frequency, and duration, as well as the association or not with other modalities of exercises (Wilmore, 1988), which showed great variability among the selected studies. Therefore, this lack of homogeneity regarding the interventions performed makes it impossible to have a clear and objective interpretation of the results achieved regarding muscle strength and its effects on functional and pulmonary capacities and possible diaphragmatic dysfunctions.

Regarding diaphragmatic dysfunctions, some studies specifically mention the decrease in diaphragmatic mobility resulting from surgical damage and also point out the benefits of IMT in the recovery of this muscle (Huang et al., 2022). IMT promotes the improvement of type II muscle fibers, directly contributing to the mobility of the injured muscle during the surgical procedure and, consequently, to the reduction of lung hyperinflation, allowing for a longer expiratory time (Tudorache et al., 2010; Kodric et al., 2013; Mehani, 2017). In this sense, IMT using respiratory trainers with linear or nonlinear pressure loads would be capable of promoting not only an increase in inspiratory muscle strength but also an improvement in diaphragmatic mobility and, consequently, a reduction in other post-surgical complications in high-risk patients (Hulzebos et al., 2006; Kodric et al., 2013; Huang et al., 2022).

However, factors such as age, sedentary lifestyle, and obesity also affect the prognosis of post-thoracic and high abdominal surgeries. Older age or lack of physical exercise may result in changes to muscle fiber composition and physical fitness, leading to decreased respiratory muscle strength, fatigue, or respiratory failure (Matsudo et al., 2000; Machado, 2012). Obesity can impair respiratory mechanics due to excess adiposity around the chest and abdomen, restricting diaphragmatic mobility and rib movement. These structural changes limit respiratory muscle function and reduce compliance, causing mechanical disadvantages in breathing. Additionally, pre-existing muscle weakness can further hinder respiratory muscle function and strength gains, increasing the risk of complications (Rasslan et al., 2004; Ramos et al., 2004; Barretta et al., 2022).

Furthermore, the lack of information regarding patients' pre-existing physical fitness levels, along with the wide age range (36.9 to 68.6 years) and body mass index variation (22.7 to 46.94 kg/m^2) in the selected studies, can also directly interfere with the interpretation of the results of this review (Santos & Antunes, 2007).

Nevertheless, the literature has shown that IMT, whether associated or not with conventional physiotherapy, is capable of reducing the loss of inspiratory muscle strength and improving inspiratory muscle endurance, favoring lung oxygenation, which echoes in the supply of muscle oxygen and, consequently, in muscle fatigue (Casali et al., 2011). Thus, it is possible to prevent and/or mitigate postoperative complications and even reduce these patients' hospital stays (Cordeiro et al., 2020; Huang et al., 2022).

Based on our findings, we conclude that IMT, either alone or in conjunction with conventional physiotherapy, is of paramount importance in the recovery of individuals undergoing thoracic or high abdominal surgery. Including IMT in pulmonary rehabilitation does not imply the inefficacy of the traditional postoperative rehabilitation protocol but rather a way to enhance the results of in-hospital physiotherapy in gaining inspiratory muscle strength. However, it is important to emphasize that improvement in inspiratory muscle strength depends on the characteristics of the studied population, the type of physical exercise, and its variables, which can be performed in different ways while respecting the particularities of the involved musculature and the individuality of the patients. Therefore, further studies with homogeneous methodologies are needed to standardize protocols and confirm the benefits of IMT, ensuring that they respect the unique attributes of the involved musculature and the individuality of each patient.

Finally, despite its relevance, the present review has some limitations that should be considered when interpreting the results. The inclusion of studies only in English and Portuguese may have restricted the scope of the analyzed evidence. Additionally, the protocol for this review was not registered in recognized platforms, and the absence of a meta-analysis prevented a quantitative synthesis of the findings.

Implications of Physiotherapy Practice

Incorporating IMT into physiotherapeutic practice for patients undergoing thoracic and upper abdominal surgeries has significant implications. IMT strengthens respiratory muscles, enhances pulmonary oxygenation, and improves oxygen delivery to muscles, helping to reduce fatigue and prevent respiratory complications such as atelectasis and pneumonia. Its regular integration into the rehabilitation programs for these patients, both independently and alongside conventional physiotherapy, can contribute to more effective recovery. However, considering protocol variability, we highlight the need for more studies to provide clear guidelines on implementing IMT in clinical settings to support its practical application. The lack of standardized protocols also underscores the need for further research to establish consistent guidelines, ensuring effective and reliable clinical outcomes.

Conclusions

IMT can enhance inspiratory muscle strength in hospitalized patients following thoracic and high abdominal surgeries. Thus, this intervention can be integrated into respiratory physiotherapy to prevent respiratory complications and reduce hospitalization duration, morbidity, and mortality.

Nevertheless, standardized protocols and further research with homogeneous methodologies are needed to confirm the benefits of IMT and establish consistent practices.

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