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ORIGINAL RESEARCH

Inspiratory muscle training in people with chronic obstructive pulmonary disease (COPD): a systematic review

Treinamento muscular inspiratório em pessoas com doença pulmonar obstrutiva crônica (DPOC): uma revisão sistemática

Entrenamiento de los músculos inspiratorios en personas con enfermedad pulmonar obstructiva crónica (EPOC): una revisión sistemática

Jennyfer Correa Mota[1], Marcilene Rodrigues dos Santos[2], Luane Rodrigues de Sousa[3], Patrick Roberto Gomes Abdoral[4], Larissa Siqueira Rodrigues Abdoral[5], Cláudia Jeane Claudino de Pontes Miranda[6]

ABSTRACT | This systematic review aimed to demonstrate the effectiveness of inspiratory muscle training (IMT) in people with chronic obstructive pulmonary disease (COPD), analyzing the effects of IMT on inspiratory muscle strength and endurance, exercise tolerance and reduction of dyspnea. A systematic search was carried out in the PubMed, Cochrane and Lilacs databases, from August 2021 to February 2023, searching for studies published from 2016. The descriptors used for the search followed the description of the MeSH/DeCS terms, namely: "Pulmonary Disease, Chronic Obstructive," "Breathing Exercises," "Exercise Tolerance," "Dyspnea," and "Muscle strength," with the languages: English and Portuguese, using the Boolean operators "AND" and "OR." Ten studies met the inclusion criteria, including 733 patients. In all examined studies, there was a significant increase in inspiratory muscle strength and endurance compared to the control group; of the ten studies analyzed, four showed advances in reducing dyspnea and exercise tolerance. Notably, inspiratory muscle training is effective in improving dyspnea, exercise tolerance, and in increasing inspiratory muscle strength and endurance in people with moderate to severe COPD.

Keywords | Pulmonary Disease; Chronic Obstructive; Breathing Exercises; Exercise Tolerance; Dyspnea; Muscle Strength.

RESUMO | O objetivo desta revisão sistemática foi evidenciar a eficácia do treinamento muscular inspiratório (TMI) em pessoas com doença pulmonar obstrutiva crônica (DPOC), analisando os efeitos do TMI na força e resistência muscular inspiratória; na tolerância ao exercício; e na redução da dispneia. Realizou-se uma busca de forma sistemática nas bases de dados PubMed, Cochrane e LILACS, no período de agosto de 2021 a fevereiro 2023, por estudos publicados a partir de 2016. Os descritores utilizados para a busca seguiram a descrição dos *Medical Subject Headings* (MeSH)/Descritores em Ciências da Saúde (DeCS), sendo eles: "*pulmonary disease, chronic obstructive*", "*breathing exercises*", "*exercise tolerance*", "*dyspnea*" e "*muscle strength*", com o filtro dos idiomas inglês e português e os operadores booleanos

[1]Universidade da Amazônia (Unama) – Belém (PA), Brazil. E-mail: jennyfercorrea2013@gmail.com. ORCID-0000-0003-1839-7416
[2]Universidade da Amazônia (Unama) – Belém (PA), Brazil. E-mail: marcilene_ifpa@hotmail.com. ORCID-0000-0003-1553-5828
[3]Universidade da Amazônia (Unama) – Belém (PA), Brasil. E-mail: luane.bs1825@gmail.com. ORCID-0000-0003-1200-5426
[4]Universidade Federal do Pará (UFPA) – Belém (PA), Brazil. E-mail: patrickabdoral@gmail.com. ORCID-0000-0001-7679-5020
[5]Universidade da Amazônia (Unama) – Belém (PA), Brazil. E-mail: larisiqueira2020@gmail.com. ORCID-0000-0001-9122-6213
[6]Universidade da Amazônia (Unama) – Belém (PA), Brazil. E-mail: cjpontes@terra.com.br. ORCID-0000-0001-9564-5298

Corresponding address: Patrick Roberto Gomes Abdoral – Rua Jabatiteua, 894 – Belém (PA), Brazil – ZIP Code: 66070-260 – E-mail: patrickabdoral@gmail.com –
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"*AND*" e "*OR*". Dez estudos cumpriram os critérios de inclusão, envolvendo 733 pacientes. Em todos os estudos examinados, houve um aumento expressivo da força e da resistência muscular inspiratória em comparação ao grupo-controle. Ainda, dos 10 estudos analisados, quatro apresentaram progressos na diminuição da dispneia e na tolerância ao exercício. Ressalta-se que o treinamento muscular inspiratório é eficaz na melhora da dispneia, da tolerância ao exercício e do aumento da força e da resistência muscular inspiratória em pessoas com DPOC em estágios moderado a grave.

Descritores | Doença Pulmonar Obstrutiva Crônica; Exercícios Respiratórios; Tolerância ao Exercício; Dispneia; Força Muscular.

RESUMEN | El objetivo de esta revisión sistemática fue evaluar la efectividad del entrenamiento muscular inspiratorio (EMI) en personas con enfermedad pulmonar obstructiva crónica (EPOC), analizando los efectos del EMI en la fuerza y resistencia muscular inspiratoria, en la tolerancia al ejercicio y en la reducción de la disnea. Se realizó una búsqueda sistemática en las bases de datos PubMed, Cochrane y LILACS, en el período de agosto de 2021 a febrero de 2023, en los estudios publicados desde 2016. Los descriptores utilizados en la búsqueda siguieron la descripción de los *Medical Subject Headings* (MeSH)/Descriptores en Ciencias de la Salud (DeCS), a saber: "*pulmonary disease, chronic obstructive*", "*breathing exercises*", "*exercise tolerance*", "*dyspnea*" y "*muscle strength*", en los idiomas inglés y portugués, y con los operadores booleanos "*AND*" y "*OR*". Diez estudios cumplieron los criterios de inclusión, en los cuales participaron 733 pacientes. En todos los estudios en análisis, se observó un significativo incremento de la fuerza muscular inspiratoria y de la resistencia en comparación con el grupo control. De los 10 estudios analizados, cuatro mostraron progreso en la reducción de la disnea y en la tolerancia al ejercicio. Cabe destacar que el entrenamiento muscular inspiratorio mostró ser eficaz en la mejora de la disnea, en la tolerancia al ejercicio y en el aumento de la fuerza y la resistencia muscular inspiratoria en personas con EPOC de moderada a grave.

Palabras clave | Enfermedad Pulmonar Obstructiva Crónica; Ejercicios Respiratorios; Tolerancia al Ejercicio; Disnea; Fuerza Muscular.

INTRODUCTION

According to the Global Initiative for Chronic Obstructive Lung Disease (GOLD)[1], chronic obstructive pulmonary disease (COPD) is common, preventable, and treatable, and is characterized by persistent respiratory symptoms and airflow limitation due to alveolar and/or airway changes, usually caused by significant exposure to harmful particles or gases. Smoking is by far the main risk factor for this disease, accounting for 40% to 70% of cases[2]. Among the typical clinical symptoms are chronic and progressive dyspnea, as well as cough and sputum production, all of which are factors that impact the health and functionality of these individuals, who may develop limitations such as: reduced exercise performance, functional losses in the lower limbs, and decreased musculoskeletal strength[3].

The prevalence of the disease has increased worldwide, and it is now considered the third leading cause of death[4]. In Brazil, according to data from the Department of Health Surveillance (*Secretaria de Vigilância em Saúde* – SVS), which follow the methodology of the Global Burden of Disease (GBD), COPD is the fifth leading cause of death among all ages[5]. In recent decades, it was the fifth largest cause for hospitalization in the Brazilian Unified Health System (SUS) among patients aged over 40 years, corresponding to about 200,000 hospitalizations, with an annual expenditure of approximately 72 million reais[6]. In the more advanced stages, COPD significantly impairs patients' quality of life, due to the most frequent and severe exacerbations, as well as functional disability associated with chronic respiratory failure, in addition to fatigue and exercise intolerance. Still, those affected in advanced stages may present weight loss, muscle mass reduction, and even cachexia, all attributed to the systemic inflammatory status.

Inspiratory muscle training (IMT), which has already been widely for treating COPD, is defined as persistent respiratory training that uses an inspiratory training device. According to the statement by the American Thoracic Society and the European Respiratory Society[7], this therapeutic resource can intensify inspiratory muscle function (strength and endurance); alleviate the sensation of dyspnea, recovering well-being; improve exercise performance; and increase total lung capacity.

IMT promotes pulmonary air outflow, increasing maximal inspiratory pressure (MIP) and, consequently, increasing inspiratory muscle strength and endurance[7].

However, despite its importance for the pulmonary rehabilitation of this public, in the last seven years, few studies were produced proving the effectiveness of the training in people with this pathology. Therefore, this aimed to evaluate clinical studies that indicated the effectiveness of IMT applied in the short, medium, and long term in people with COPD, analyzing the potential benefits of training for inspiratory muscle strength and endurance, reduction of dyspnea, and exercise tolerance.

METHODOLOGY

Research strategy

This systematic review was developed according to the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[8]. To increase the quality of the work with a rigorous design methodology, the search was carried out by consulting several online databases.

In the National Library of Medicine (PubMed), the filters used were "clinical trials"; "controlled and random testing"; "last seven years of publication"; and "adult population." In the Cochrane Library, the study models with intervention therapies and the filters "last seven years of publication" and "studies published in English and Portuguese languages" were prioritized. In the database Latin American and Caribbean Health Sciences Literature (LILACS), the selected filters were "main subject chronic obstructive pulmonary disease"; "controlled clinical trials"; "English and Portuguese languages"; and "last seven years of publication."

The search comprised the period from August 2021 to February 2023, and the descriptors used followed the description of the Medical Subject Headings (MeSH)/ Health Sciences Descriptors (DeCS), which were: "pulmonary disease, chronic obstructive"; "breathing exercises"; "exercise tolerance"; "dyspnea"; and "muscle strength," with the Boolean operators "AND/*E*" and "OR/*OU*."

Inclusion and exclusion criteria

This review included randomized clinical trials that had as their object of observation individuals aged over 18 years, diagnosed with moderated to severe COPD, and in which IMT was employed as one of their interventions.

Similarly, studies focused on individuals with other chronic respiratory diseases and who were in another type of rehabilitation program were excluded. Studies with titles and abstracts that did not contemplate the subject of this study were also disregarded, as well as incomplete studies.

Data extraction

In the formulation of the guiding question, the strategy used was the Population, Intervention, Comparison, and Outcome (PICO); in the delimitation of the population, people with COPD were considered; IMR was selected as the applied intervention; the included studies had a control group and an intervention group; and the main outcomes analyzed were inspiratory muscle strength and endurance, exercise tolerance, and reduction of dyspnea. The data collection procedures occurred in four stages, namely: identification, selection, eligibility, and inclusion.

The entire review process of the articles identified with the search strategy was carried out independently by two researchers, by first reading titles and abstracts to evaluate the status of the articles. When there was a divergence of opinion among the researchers, the opinion of a third researcher was requested.

RESULTS

In the identification stage of this research, 558 studies were found in PubMed, 107 in Cochrane, and 12 in LILACS, totaling 677 articles. After applying the inclusion and exclusion criteria, 52 articles were encompassed by the analysis, with the subsequent exclusion of 21 duplicate articles. Then, during the full reading of the remaining 31 articles, 10 were selected, composing this study universe of analysis. The flowchart (Figure 1) shows the screening process.

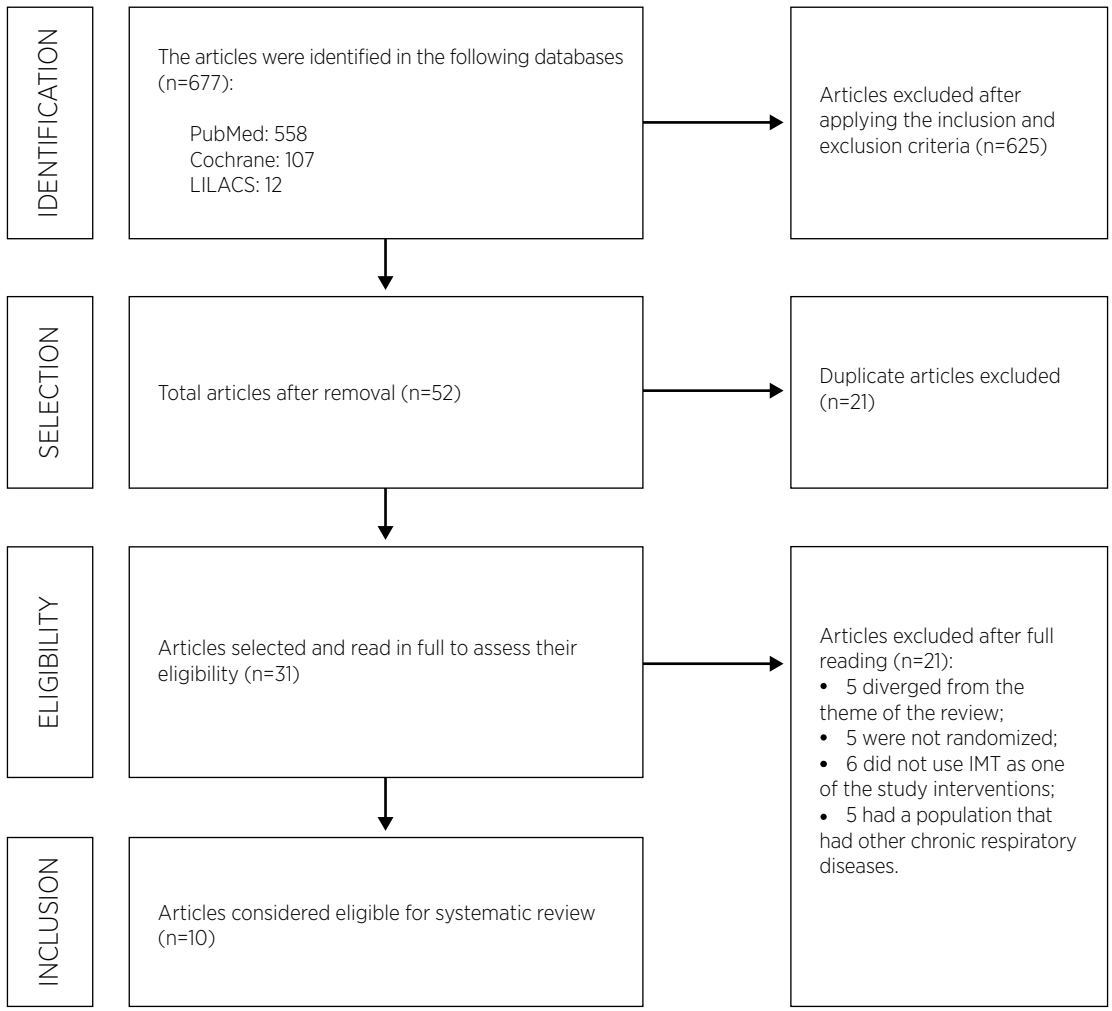

Figure 1. Article selection flowchart

Thus, 10 studies, from the total of 733 patients, met the inclusion criteria and were selected for review. After analyzing the articles and choosing them according to the proposed methodology, we applied the data extraction form to collect the main information of each study—authorship, year of publication, type of study, sample of the population surveyed, study groups, intervention, and results. All this information was gathered and is organized in Chart 1.

Chart 1. Data extraction form

Authorship (year)	Type of study	Sample	Groups	Intervention	Results		
					Increased inspiratory muscle strength and endurance	Improved exercise tolerance	Decreased dyspnea
Cutrim et al.[9] (2019)	Randomized clinical trial	Male: 17 Female: 5 Age: ±66 to 80 years	IMTG (11) CG (11)	Training time: 30min*/day Training frequency: 3×/week Total intervention time: 12 weeks Device used: Threshold Inspiratory Muscle Training; POWERbreathe Medic +Plus Load adopted: 30% of the initial MIP*. CG: control group who received no intervention and was evaluated before and after 12 weeks.	IMTG showed improvement in MIP after 12 weeks when compared with the control group. The MIP of the study participants before the intervention was ±62cmH_2O*; after the intervention, the MIP was ±84cmH_2O.	IMTG showed no significant improvement in exercise tolerance when compared with CG in the 6MWT.	IMTG did not show significant improvements in the reduction of dyspnea when compared with CG in the 6MWT.
Chuang et al.[10] (2017)	Randomized Clinical Study	Male: 36 Female: 19 Age: ≥66	IMTG (27) CG (28)	Training time: 21 to 30min/day, consisting of a IMT cycle of 2min and 1min of rest; and then seven repeated cycles. Training frequency: 5×/week Total intervention time: eight weeks. Device used: NS Load adopted: NS CG: only medical treatment and routine care were provided, without intervention.	IMTG showed significant improvement in MIP when compared with CG. The mean improvement in MIP in the IMT group was (−17.6±0.18cmH_2O), while in the CG it was (−2.21±0.4cmH_2O)	IMTG showed an increase in distance in the 6MWT of 47.8±1.46 meters, while CG showed an increase of 5.6±1.1 meters.	IMTG showed an increase in BDI, from 4.48±2.12 points to 9.0±2.27 points. Consequently, there was a reduction in dyspnea.
Langer et al.[11] (2018)	Study Clinical Randomized	Male: 7 Female: 13 Age: ≥70	IMTG (10) CG (10)	Training time: 15min/session Training frequency: 2 to 3×/day, 4 to 7×/week. Total intervention time: eight weeks. Device used: electronic device POWERbreathe KH2. Adopted load: initial load was ±40% of the base MIP and was progressively increased up to 40% to 50% of the current MIP. CG: performed three daily sessions with unchanged load of ≤10% of the initial MIP.	IMTG showed significant improvement in MIP after the intervention: the initial value (−76±16cmH_2O) increased to −80±15cmH_2O after IMT.	IMTG showed reduced dyspnea during cycling exercise. It was observed that the exercise time increased more in the IMT group when compared with the CG.	IMTG showed a significant decrease in the dyspnea scale, whose initial value was 3.0±1.0; and after the intervention, 2.9±1.0. Unlike the CG, which maintained the same pattern (3.0±1.1).
Charususin et al.[12] (2018)	Randomized clinical trial	Male: 95 Female: 124 Age: ≥65	IMTG (85) CG (89)	Training time: 60min/session. Training frequency: 3 to 5 sessions/week. Total intervention time: from 20 to 36 sessions. Device used: POWERbreathe KHP2. Load adopted: NS CG: Both groups undertook an identical general training program. However, the intensity of training in the intervention group was initially defined as a load of approximately 50% of the maximum inspiratory pressure of the patient's mouth (MIP). The training intensity in the control group was set at 10% of baseline MIP and was not modified throughout the intervention period.	IMTG showed greater improvements in inspiratory muscle strength when compared with CG. The baseline MIP training load in the first week was 47±2% and evolved to 84±4% of their baseline MIP at week 12.	IMTG showed an additional 75s improvement in endurance time in cycling exercise. However, no significant differences were observed between IMTG and CG in the 6MWT.	IMTG showed significant reductions in the Borg dyspnea score during the cycling test, after IMT.

(continues)

Chart 1. Continuation

Authorship (year)	Type of study	Sample	Groups	Intervention	Results		
					Increased inspiratory muscle strength and endurance	Improved exercise tolerance	Decreased dyspnea
Mehani[13] (2017)	Randomized clinical trial	Male: 40. Age: ≥59	IMTG (20) CG (20)	Training time: six sessions of five deep breaths each. Training frequency: 3×/week Total intervention time: two months. Device used: Threshold/Respironics Inc. Load adopted: 15% of baseline MIP, increasing by 5% to 10% to reach 60% of baseline MIP. They also received placebo EMT with a fixed load of 7cmH_2O. CG: Received EMT with an initial load of 15% of their baseline MEP and progressively increased to 60%. They also received placebo IMT with a fixed load of 7cmH_2O.	IMTG showed a significant increase in MIP, and the initial value of −0.59±0.83cmH_2O increased to −23.18±4.63cmH_2O after the intervention.	IMTG expressed a significant increase in the 6MWT, about 25% when compared with the CG, which had an increase of 2.5%.	This variable was not evaluated in the study.
Beaumont et al.[14] (2018)	Randomized clinical trial	Male: 94 Female: 55 Age: 60 to 65 years	GTMI+PR (74) CG (75)	Training time: 15min/session Training frequency: 2 sessions/day, 5×/week. Total intervention time: four weeks Device used: PowerBreathe Medic. Load adopted: 50% of the initial MIP of each session, the load was increased (±10%) after 10 days of training during the program, to reach 60% of the initial MIP. They also received a standardized pulmonary rehabilitation program. CG: received a standardized PR program for a period of four weeks.	IMTG showed a significant increase in MIP (−14.8cmH_2O) when compared with CG, which showed an increase of −9.9cmH_2O.	IMTG reported no significant difference in the 6MWT.	IMTG showed a reduction in dyspnea, assessed using the Borg scale and the mMRC scale. (Borg 5.4±2.2 to 4.0±2.1; mMRC 2.3±1.1 to 1.4±1.2)
Wu et al.[15] (2017)	Randomized clinical trial	60 patients Sex: NS Age: 59 to 62 years	IMTG 1 (21) IMTG 2 (19) CG (20)	Training time: 30min/day, divided into two cycles of 15min. Training frequency: 7×/week Total intervention time: eight weeks. Device used: IMTG 1 used the Inspiratory Resistive Training PFLEX device; IMTG 2 used the Threshold Inspiratory Muscle Training device. Load adopted: 60% of MIP. CG: did not receive any intervention other than medication, did not include any rehabilitation program for eight weeks.	GTMI 1 showed a significant increase in inspiratory muscle strength after IMT. MIP increased from −37.31±6.18cmH_2O to −45.77±5.84cmH_2O after IMT. IMTG 2 also showed improvement in inspiratory muscle strength: MIP increased from −37.53±6.46cmH_2O to −45.11±8.71cmH_2O after IMT. There was no significant difference between IMT groups 1 and 2.	The intervention groups significantly increased in the duration of cycling exercise. The IMTG 1 went from 401.84±97.29s to 405.58±96.57s. While IMTG 2 went from 429.10±105.50s to 522.05±129.41s, indicating increased exercise tolerance.	The IMT groups, in the BDI*, showed improvement after the IMT. IMTG 2: 2.52±2.04; IMTG 1: 1.58±2.93, significant improvement compared with CG (0.30±3.31). There was no significant difference in BDI between the three groups.

(continues)

Chart 1. Continuation

Authorship (year)	Type of study	Sample	Groups	Intervention	Results		
					Increased inspiratory muscle strength and endurance	Improved exercise tolerance	Decreased dyspnea
Arnedillo et al.[16] (2020)	Randomized clinical trial	16 patients Sex: NS Age: ≥65	IMTG (7) CG 1 (5) CG 2 (4)	Training time: 60min/session. Training frequency: 3×/week Total intervention time: eight weeks. Device used: nasal restriction device for inspiratory muscle training called Feelbreathe, associated with a PR program composed of warm-up phase, main phase, and recovery phase. Load adopted: NS. CGs: CG 1 received the same pulmonary rehabilitation as the intervention group, but without IMT (Feelbreathe). CG 2 received standard medical recommendations for patients with COPD.	IMTG achieved a significant increase in MIP when compared with CG 1 and CG 2.	IMTG obtained a greater increase in the distance covered in the 6MWT in relation to CG 1 and CG 2.	This variable was not evaluated in the study.
Xu et al.[17] (2018)	Randomized clinical trial	Male: 82 Female: 5	IMTG (21) CG A (22) CG B (22) CG C (22)	Training time: 48min/session, 3min of training and 2min of rest. Training frequency: 7×/week Total intervention time: eight weeks. Device used: Threshold IMT and Threshold PEP. Load adopted: NS. The IMT group performed eight series of IMT and eight series of respiratory muscle training without any daily load. CGs: CG A performed 16 training sets daily, combined with a respiratory cycle. CG B performed eight series of IMT and eight series of EMT separately in different daily cycles. CG C performed 16 sets of respiratory muscle training without any daily load.	The MIP of IMTG, CG A, and CG B was significantly higher than CG C (only group that did not perform IMT).	IMTG, CG A, and CG B showed a decrease in the degree of dyspnea, indicating that respiratory muscle training can relieve dyspnea in patients with COPD.	IMTG did not show significant improvements in the reduction of dyspnea, when compared with the control groups in the 6MWT.
Buran Cirak et al.[18] (2022)	Prospective, randomized, double-blinded, placebo-controlled study	Male: 49 Female: 11 Age: ≥62	IMTG (30) CG (30)	Training time: 15min/day. Training frequency: every day. Total time of the intervention: 12 weeks Device used: Threshold IMT. Load adopted: 40% of the initial MIP. CG: control group who received no intervention and was evaluated before and after 12 weeks.	IMTG showed improvement in MIP after 12 weeks when compared with CG. The MIP of the study participants before the intervention was ±62cmH_2O*; after the intervention, the MIP was ±84cmH_2O.	The studied group (395.1-467.2) did not present significant improvements in exercise tolerance when compared with the CG (386.7-430.2) in the 6MWT.	The benefit of IMT in dyspnea was evaluated using the dyspnea scale, showing a decrease in dyspnea in both groups, but a more noticeable decrease in symptoms in IMTG.

NS: not stated; IMTG: inspiratory muscle training group; CG: Control group; IMTG 1: resistive IMT; IMTG 2: Threshold IMT; IMTG A: pulmonary rehabilitation+Feelbreathe (IMT) group; CG 1: pulmonary rehabilitation group + oronasal breathing without Feelbreathe; CG A: inspiratory and expiratory muscle training group in the same respiratory cycle; CG B: inspiratory and expiratory muscle training group separately in different respiratory cycles; CG C: simulated training group; IMT: inspiratory muscle training; MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure PR: pulmonary rehabilitation; 6MWT: 6-minute walk test; mMRC: Modified Medical Research Council scale; BDI: baseline dyspnea index; cmH_2O: centimeters of water; EMT: expiratory muscle training; min: minutes; s: seconds.

All articles included older people, with the lowest age observed being 59 years and the highest 70 years. Only two studies did not adjust the analysis by sex[15,16], and one study analyzed only males[13]. The main variables that this review chose to observe in the studies were increased inspiratory muscle strength and endurance, as well as decreased dyspnea and/or improved exercise tolerance.

Some of the studies used the 6-minute walk test (6MWT), as well as the cycling test on cycle ergometer. From this, the information on the variables were gathered, as summarized in Chart 1.

Methodological qualification

The quality of the chosen articles was measured by the Cochrane risk-of-bias tool for randomized trials (RoB 2)[19], which contains five domains for assessing methodological quality and the risk of bias due to: randomization processes; deviations from the intended interventions; lack of information; data measurement; and selection of reported results. The five items in RoB 2 are classified into "low risk of bias," "uncertain risk of bias," and "high risk of bias." This tool was applied by two independent evaluators and, in case of divergence of opinions, they sought a consensus; when the difficulty persisted, a third evaluator interfered, deciding the classification of the risk of bias (Chart 2).

In addition to the methodological evaluation for the analysis of the risk of bias, we also used the PEDro[20] scale (Chart 3), whose objective is to help researchers quickly identify whether the selected articles followed the appropriate methodological rigor for a clinical trial.

Chart 2. Cochrane risk-of-bias tool for randomized trials quality scale

COCHRANE SCALE	Randomization sequence generation	Allocation secrecy	Blinding of participants and staff	Blinding of outcome assessment	Incomplete outcome data	Selective reporting of outcomes	Other sources of bias
Cutrim et al.[9] (2019)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Uncertain risk
Chuang et al.[10] (2017)	Low risk	Low risk	Low risk	Uncertain risk	Low risk	Low risk	Uncertain risk
Langer et al.[11] (2018)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Uncertain risk
Charususin et al.[12] (2018)	Low risk	Low risk	Low risk	Uncertain risk	Low risk	Low risk	Uncertain risk
Mehani[13] (2017)	Low risk	Low risk	Uncertain risk	Low risk	Low risk	Low risk	Uncertain risk
Beaumont et al.[14] (2018)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Uncertain risk
Wu et al.[15] (2017)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Uncertain risk
Arnedillo et al.[16] (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Uncertain risk
Xu et al.[17] (2018)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Uncertain risk
Buran Cirak et al.[18] (2022)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Uncertain risk

Chart 3. Evaluation by the PEDro scale

Criteria	Cutrim et al.[9] (2019)	Chuang et al.[10] (2017)	Langer et al.[11] (2018)	Charususin et al.[12] (2018)	Mehani[13] (2017)	Beaumont et al.[14] (2018)	Wu et al[15] (2017)	Arnedillo et al.[16] (2020)	Xu et al.[17] (2018)	Buran Cirak et al.[18] (2022)
Eligibility criteria have been specified	1	1	1	1	1	1	1	1	1	1
The subjects were randomly distributed into groups (in a crossover study, the subjects were randomly placed in groups according to the treatment received)	1	1	1	1	1	1	1	1	1	1
The allocation of subjects was secret	1	1	1	1	1	1	0	0	1	1
Initially, the groups were similar concerning the most important prognostic indicators	1	0	1	1	1	0	1	1	1	1
All subjects were blinded in the study	0	1	1	1	1	1	0	0	0	0

(continues)

Chart 3. Continuation

Criteria	Cutrim et al.[9] (2019)	Chuang et al.[10] (2017)	Langer et al.[11] (2018)	Charususin et al.[12] (2018)	Mehani[13] (2017)	Beaumont et al.[14] (2018)	Wu et al[15] (2017)	Arnedillo et al.[16] (2020)	Xu et al.[17] (2018)	Buran Cirak et al.[18] (2022)
All the therapists who administered the therapy did so blindly	0	0	0	1	1	1	0	0	0	0
All evaluators who measured at least one key outcome did so blindly	1	0	1	1	1	1	0	0	0	0
Measurements of at least one key outcome were obtained in more than 85% of the subjects initially distributed in the groups	1	1	1	1	0	1	1	0	1	1
All subjects from whom outcome measurements were presented received the treatment or control condition according to allocation or, when this was not the case, data analysis of at least one of the key outcomes was performed by "intention to treat"	1	1	1	1	1	1	1	1	1	1
The results of the intergroup statistical comparisons have been described for at least one key result	1	1	1	1	1	1	1	1	1	1
The study presents both precision measures and measures of variability for at least one key outcome	1	1	1	1	1	1	1	1	1	1
Total score for PEDro scale	9	8	10	11	10	10	7	6	8	8

0 indicates that the study did not contemplate the criterion, and 1 indicates that the study contemplated it.

DISCUSSION

The findings demonstrate that IMT is beneficial and effective in the treatment of patients with COPD, providing increased inspiratory muscle strength and endurance; reduction of dyspnea; and improved exercise tolerance. The analyzed studies highlight that individuals who performed continuous IMT sessions significantly reduced shortness of breath[10-12,14,15,17,18], improved exercise tolerance[10-16,18], and increased inspiratory muscle strength[9-15,17,18], when compared with control groups not subjected to IMT.

The common intolerance to physical exercise presented by the population affected by COPD is caused by a ventilatory disorder, a dysfunction of the peripheral muscles; consequently, these people experience physical exercise restriction, reduced activities of daily living (ADLs), airflow limitation, pulmonary hyperinflation, and inspiratory muscle weakness[21].

In patients with COPD, the metaboreflex of the inspiratory muscles is increased, and one of the IMT responses is to assist its reduction. According to Richardson et al.[22], patients with COPD present a decrease in type I fibers, which are rich in mitochondria; thus, there is a loss of oxidative capacity of the musculoskeletal system of these individuals.

During IMT exercises, there is a decrease in metaboreflex in patients with COPD. Among the mechanisms that may contribute to this alteration in muscle metabolic activity, one can include the decrease in the supply of oxygen to the musculature or the lower efficiency of the muscular oxidative metabolism.

Gosselink et al.[23] conducted a meta-analysis of 32 randomized clinical trials on the effects of IMT in patients with COPD, demonstrating that increasing patients' MIP to 13cmH_2O after training was associated with clinical improvement. Similarly, in the study by Chuang et al.[10], a randomized clinical trial with 55 participants, aged 66 years or older, of both men and women, showed that after eight weeks of IMT there was an improvement of approximately 18cmH_2O in the MIP of the individuals. The MIP is an index of inspiratory

muscle strength, being the highest pressure that can be generated during an inspiration with airway occlusion, measured with a respiratory pressure meter.

Similarly, the randomized clinical trial by Arnedillo et al.[16] with 16 participants, aged 65 years or older, without defining the gender of the participants, showed an increase in inspiratory muscle strength after eight weeks of training. However, the group that did not receive the intervention did not present any alteration in this variable, which allows us to infer that the IMT actually increases the strength of the inspiratory muscles, with consequent clinical improvement.

Several studies have shown that the population studied has impaired respiratory muscle strength[24-27]. Therefore, the improvement in exercise tolerance may be a result of increased inspiratory muscle strength, which was evidenced by Ramirez-Sarmiento et al.[28] in a randomized clinical trial that performed IMT for 30 minutes per day, five times per week, over five weeks of intervention, attesting that IMT induces functional improvement and adaptive changes in inspiratory muscle structures. Dekhuijzen et al.[29], also in a randomized clinical trial, showed that a rehabilitation program that uses IMT increases the strength of the inspiratory muscles in patients with COPD, in agreement with what Charususin et al.[12] concluded in a randomized clinical trial with 219 patients, both men and women, aged 65 years or older.

From a mechanistic perspective, according to Mehani[13], IMT improves the capacity of the inspiratory muscles, significantly increasing the size of type II muscle fibers. Furthermore, IMT can increase the shortening speed of these muscles, allowing more time for expiration and reducing pulmonary hyperinflation.

This review showed that 6 of the 10 included studies[10-13,15,16], reported that IMT improves exercise tolerance, and the same proportion[10-12,14,15,17] attested that the treatment reduced dyspnea in patients with COPD. The result is similar to the previous study by Bavarsad et al.[30], in which they proved that short-term IMT has beneficial effects on exercise tolerance and on the reduction of dyspnea, especially in patients with COPD. However, these findings defy the studies by Cutrim et al.[9], Beaumont et al.[14] and Xu et al.[17] since they found no evidence that IMT brings improvements in exercise tolerance.

Dyspnea is due to alveolar dysfunctions that cause increased subjective feelings of tiredness, shortness of breath, and difficulty breathing in patients with COPD when performing any physical activity[31-33]. In this scenario, IMT proved to be a mitigating intervention in six of the included studies[10-12,14,15,17]. On the contrary, the study by Cutrim et al.[9] did not observe progress resulting from IMT in dyspnea, but these findings were possibly affected by the sample size, since the studies that demonstrated the benefit of IMT included robust samples[10,14,15,17].

Despite the important findings of this review regarding the advantages of IMT for inspiratory muscle strength, reduction of dyspnea, and exercise tolerance in patients with COPD, it is necessary to highlight some limitations, such as the heterogeneity of the IMT program applied, their duration ranged from 4 to 36 weeks and from 5 to 60 minutes per session, and their intensity from 15% to 60% of MIP. Another limitation is the size of the study samples, with some with a very small number of participants. Still, the data from this review cannot be extrapolated to all degrees of COPD since the studies focused on patients with moderate to severe classification. Finally, the temporal choice of articles published in the last seven years can also be considered a limitation.

CONCLUSION

This systematic review suggests that inspiratory muscle training is effective in improving dyspnea, exercise tolerance, and inspiratory muscle strength and endurance in patients with COPD in moderate to severe stages. One of the limitations presented in the clinical trials included in the review was the heterogeneity of IMT interventions; the studies did not follow a standard protocol, and many of them did not clearly specify the modalities of IMT programs applied to patients.

We observed that even the studies that adopted IMT of low frequency and intensity obtained positive results, even in a short period of time. Further clinical studies on IMT and its relationship with COPD are needed.

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