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Effects of inspiratory muscle training on functional fitness in obese and overweight adults: A systematic review of randomised control trials

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ABSTRACT

Background: Obesity is a chronic metabolic disorder that affects the cardiopulmonary system. Its management, mainly, focuses on weight loss programmes without incorporating respiratory management. Threshold inspiratory muscle trainers (IMT) was used to strengthen inspiratory muscles and improve functional exercise capacity in obese and overweight individuals.

Objective: To investigate the effectiveness of IMT on functional fitness in overweight and obese individuals.

Methods: An electronic search was conducted in Scopus, PubMed, Web of Science, Dimension, Medline, and Open Alex database. The review included studies of randomised controlled trials (RCTs), which were conducted for the last 20 years on healthy adults with obesity, and the studies investigating the effects of IMT on multiple parameters. The revised Cochrane risk of bias tool (RoB 2.0) was employed to assess the methodological quality of the included studies.

Results: The initial search yielded 832 studies. Ultimately, five randomised control trials with three to four measurement outcomes were included. Inspiratory muscle strength and functional capacity outcomes were measured, with pre- and post-IMT intervention assessments performed. Results suggest that IMT improves functional capacity (6MWT) and inspiratory muscle strength without a significant difference in the pulmonary function test.

Conclusion: IMT improves inspiratory muscle strength and functional capacity in obese and overweight adult individuals. Healthcare professionals should consider including IMT to any prescribed rehabilitation program particularly for those with obese and overweight.

Keywords: inspiratory muscle training, obesity, respiratory muscle strength, maximum inspiratory pressure, functional capacity, pulmonary function test

INTRODUCTION

Obesity is a health condition which is linked to significant morbidity and mortality. The World Obesity Atlas 2025 reports that over 39 % of the global population suffers from either overweight or obesity. Without significant interventions, this number is expected to increase to 50% by 2030 [1]. Obesity increases the risk of cardiovascular, metabolic and respiratory diseases because it is associated with excessive build-up of fatty tissue, increases in body mass index (BMI), and reduction in the quality of life [2, 3]. The high values of BMI have negative impacts on lung volume and airway hypersensitivity [4-6]. Many exercises training is being used to reduce extra weight and to enhance health outcomes in obese individuals. Unfoareeunately, the efficacy of exercise training is affected by shortness of breath and premature fatigue, which reduces the motivation to continue training programmes [7]. Easy fatigue and shortness of breath during exercise may be as a result of accumulation of fatty tissues in the abdominal area, which may alter the normal function of breathing [8]. In addition, overstretching in the fibres of the diaphragm in obese individuals causes a decrease in cardiopulmonary endurance and weakness in the diaphragmatic functions. Individuals with weakness in the diaphragm suffer from reduced lung capacity, which increases the metabolic requirements of the respiratory muscles, airway resistance and breathing difficulties. Moreover, fat around the trunk causes a reduction in chest wall compliance. These factors cause weakness and fatigue in the respiratory muscles, in addition to exercise intolerance [8].

Obese individuals often breathe rapidly and shallowly, which raises the oxygen cost and compromises blood flow to

Table 1. PICOS criteria were used to define the research question

Acronym	Definition	Description
P	Participants	Overweight and obese adults (aged 20-60 years) who is free from any cardiopulmonary or neurological disorders with BMI> 23 kg/m^2 (based on the Asian classification of obesity)
I	Intervention	Trained with Inspiratory Muscle Trainer device for a minimum duration of 4 weeks.
C	Comparison	Placebo sham control group (10% IMT intensity).
O	Outcomes	Functional exercise capacity and maximum inspiratory pressure.
S	Study designs	Randomised control trials.

the legs. This limits the maximal oxygen uptake (VO_2), which is defined as the maximal oxygen consumed during maximal exercise intensity [9-11].

Respiratory muscles are a type of skeletal muscle whose contraction produces changes in chest wall movement during inhalation and exhalation. When resistance and endurance training are applied to the respiratory muscle, there will be plasticity by remodelling their cross-sectional area, muscle fibre phenotype and threshold for activation. Applying resistive loads for long periods and adjusting these loads to the respiratory muscle will improve the strength and endurance of the respiratory muscle. When respiratory muscles are sequentially overloaded, their response will be hypertrophy which will enhance contractile force, which leads to improved chest wall mechanics and lung volumes [12].

Threshold inspiratory muscle training (IMT) indues a pressure-based loading device with a spring-loaded valve and mouthpiece at one end to impede airflow, the user tries to create enough inspiratory pressure to overcome valve resistance. IMT strengthen the respiratory muscles and improve functional exercise capacity [13]. The muscles of respiration are skeletal muscles, thus they grow in size and strength with exercise training [14].

Overweight and obese individuals commonly tend to focus on weight reduction through diet programs and general physical activity, they neglect IMT in their aerobic training which predispose to shortness of breath and premature fatigue even though it might be very beneficial for increasing their functional capacity and improving the strength of their respiratory muscle [15].

A randomised control trial was conducted on obese adults to investigate the outcomes of six-week training sessions using an IMT device on pulmonary function test (PFT) and physical capacity. The results show a significant improvement in endurance capacity and performance of the 6-minute walk test in the IMT group (+12.9%, $p=0.001$) and a more significant improvement in maximal inspiratory pressure (+49.6%, $p<.001$) in the IMT group [16].

Furthermore, a randomised control study was performed on 67 obese adults for four weeks to test the influence of IMT on functional fitness. They determined significant improvements in the inspiratory muscle strength in the IMT group (19 cm H_2O, $p < 0.01$). Moreover, the distance for walking post-training was improved significantly ($p < 0.01$), but both outcomes remained the same for the control group without any changes [17].

A systematic review is needed to investigate the effectiveness of IMT on functional capacity and the strength of the inspiratory muscle in obese and overweight individuals who do not have any cardiopulmonary, musculoskeletal or neurological disorders since no systematic review has been done until now. There are only a small number of randomised control trials and only one systematic review was done previously to determine the effectiveness of IMT in obese patients with comorbidity diseases [18].Thus, this study aimed to conduct a systematic review of the effectiveness of IMT on inspiratory muscle strength and functional capacity in overweight and obese adults who don't have any cardiopulmonary, musculoskeletal and neurological disorders based on the available studies in the literature.

The research question for this systematic review:

RQ1 Does the IMT improve the respiratory muscle strength and functional capacity of overweight and obese adults who don't have any cardiopulmonary, musculoskeletal and neurological disorders?

METHODS

This systematic review is registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the number (CRD42023472148). The Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines were used to conduct this study. The PICOS strategy was applied to identify the question of the study, as presented in **Table 1**.

Eligibility Criteria

The current study included only the conducted randomised control trial studies in obese and overweight adults with BMIs of over 23 kg/m^2 according to the Asian classification of obesity; the participants also had to be between 20 and 60 years old and free from any affecting and chronic cardiopulmonary or neurological disorders. Only articles published in peer reviewed journals with the full text in the English language were included. The studies that used inspiratory muscle training methods other than IMT devices were excluded.

Information Sources and Search Strategy

An electronic search was performed on five databases (Web of Science, Scopus, PubMed, Dimensions and Open Alex) by the first author (MMA) and (SA) on 21 April 2024.

A comprehensive search strategy was developed using terms related to Respiratory Muscles ('Respiratory Muscles' OR 'Inspiratory Muscle Training' OR 'Breathing Exercises'), physical Fitness ('Physical Fitness' OR 'Functional Fitness' OR 'Aerobic Exercise*'), and Obesity ('Overweight' OR 'Obesity'). The search strategy for used databases is provided in **Table 2** with the descriptors of the population of interest used.

The Process of Selection, Data Collection and Extraction

Two independent reviewers (MMA & SA) screened titles and abstracts for eligibility. Full-text articles were retrieved for studies meeting the inclusion criteria. Disagreements between reviewers were resolved by discussion. Data were extracted independently by two reviewers (MMA & SA) using a standardized data extraction form. Discrepancies in data extraction were resolved through discussion. Using forward

Table 2. Database formulas used for the literature search

Source	Database formulas
Scopus	TITLE-ABS-KEY (‘Respiratory Muscles’ OR ‘Inspiratory Muscle Training’ OR ‘Breathing Exercises’) AND TITLE-ABS-KEY (‘Physical Fitness’ OR ‘Functional Fitness’ OR ‘Aerobic Exercise*’) AND TITLE-ABS-KEY (‘Overweight’ OR ‘Obesity’)
Web of Science	TS = (‘Respiratory Muscles’ OR ‘Inspiratory Muscle Training’ OR ‘Breathing Exercises’) AND TS = (‘Physical Fitness’ OR ‘Functional Fitness’ OR ‘Aerobic Exercise*’) AND TS = (‘Overweight’ OR ‘Obesity’)
PubMed Species: Humans	(‘Respiratory Muscles’[Mesh] OR ‘Inspiratory Muscle Training’ OR IMT OR ‘Breathing Exercises’) AND (‘Physical Fitness’[Mesh] OR ‘Functional Fitness’ OR ‘Aerobic Exercise*’) AND (Overweight [Mesh] OR Obesity [Mesh])
Dimensions	(‘Respiratory Muscles’ OR ‘Inspiratory Muscle Training’ OR ‘Breathing Exercises’) AND (‘Physical Fitness’ OR ‘Functional Fitness’ OR ‘Aerobic Exercise*’) AND (‘Overweight’ OR ‘Obesity’)
Open Alex	(‘Respiratory Muscles’ OR ‘Inspiratory Muscle Training’ OR ‘Breathing Exercises’) AND (‘Physical Fitness’ OR ‘Functional Fitness’ OR ‘Aerobic Exercise*’) AND (‘Overweight’ OR ‘Obesity’) AND (‘Randomized Control Trial’ OR RCT)

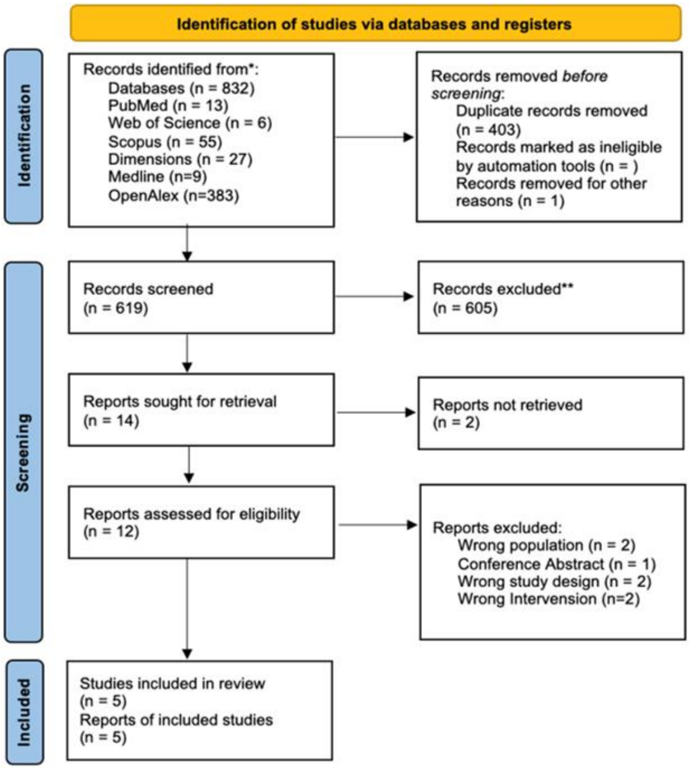

Figure 1. PRISMA flowchart of the study selection and screening process (Source: Authors’ own elaboration)

and backward citation searching through the Citation Chaser application software, more articles were found in the references cited in the paper [19]. Subsequently, Rayyan Software was used to remove duplicate studies [20]. The full text was then read to collect the needed information. The following data were extracted from the selected studies: number and characteristics of participants, type of intervention, training protocol (i.e., number of sets and repetitions, frequency and intensity), outcome measurements, results, and conclusion.

Appraisal of Methodological Quality

The revised Cochrane risk of bias tool (RoB 2.0) was used to assess the methodological quality of the selected studies. Rob 2.0 comprises five domains, rated from low risk to some concern and high risk. The five domains used for assessing bias include the process of randomisation, deviations from the intended intervention, missing outcome data, the measurement of the outcome, and the selection of the reported results. Two reviewers (MMA)and (SA) rated the articles independently, and any differences in opinion were resolved by agreement.

RESULTS

Selection of Studies

The initial search of the five databases yielded 832 articles. From these articles, 404 duplicate studies and one retracted article were removed. Fourteen of the remaining 619 titles and abstracts were assessed as full texts. Nine of them were excluded on the following bases: two studies were not available as full texts, two studies had different interventions, one study had only a conference abstract, two studies had paediatric participants, and two studies did not use a randomized control study design. Thus, 614 of the 619 studies were excluded because they did not meet the inclusion criteria, and only five studies were finally included in the systematic review [3, 7, 8, 16, 17]. **Figure 1** presents the PRISMA flowchart of the study selection and screening process.

Study Characteristics

Table 3 and **Table 4** summarise the characteristics of the included studies. **Table 4** lists the characteristics of the interventions, the outcomes, and the results. All the studies were published between 2012 and 2021.

Table 3. Characteristics of the included studies

Author, year	Group	Participants (M/F)	Age (Years) mean ± SD	BMI (kg/m^2)
Edwards et al. (2012) [7]	Experimental	15 adults n=8 (4/4)	49 ± 8.60	34.5 ± 8.4
	Placebo	n=7 (3/4)	55 ± 11.00	32.8 ± 4.8
Tenório et al. (2013) [3]	IMT	n=7	37.85 ± 9.30	45.64 ± 4.73
	Control	n=7	33.42 ± 8.50	44.87 ± 3.60
Edwards et al. (2016) [17]	Experimental	n=35(19/16)	46 ± 7.50	36.8 ± 7.4
	Placebo	n=32(18/14)	48 ± 11.00	35.2 ± 5.9
Kuo et al. (2020) [16]	IRT	n=16(3/13)	37.6 ± 8.80	30.5 ± 2.8
	Placebo	n=12(4/8)	37.5 ± 8.50	31.1 ± 3.1
Ponde et al. (2021) [8]	Group A	n=30	24.20 ± 4.11	23 to 29
	Group B	n=30	22.87 ± 3.85	23 to 29

M, Male; F, Female; BMI, Body Mass Index; number of participants; MT, Inspiratory Muscle Trainer; IRT, Inspiratory Resistive Trainer

Table 4. Characteristics of intervention

Study	Intervention		Control group	Outcomes	Results
	Load of IMT device	Time/frequency			
Edwards et al. (2012) [7]	55%	Two sets of 30 repetitions every day for 4 weeks.	Placebo followed the same IMT protocol but with 10% MIP	RMS, pulmonary function and (6MWT, VO_2)	-No significant difference in lung function (FEV_1/ FVC) and VO_2 max after IMT for both groups -Improved MIP after IMT for EXP group -Improved 6-minute walking distance after IMT for EXP group -For the placebo group the outcome measurements did not significantly change
Tenório et al. (2013) [3]	30%	Two sessions of 15 minutes every day, five days in a week for 12 weeks.	Followed the same IMT protocol but without inspiratory load	RMS, pulmonary function, MVV and diaphragmatic mobility	-Significant increase in PI max and MVV and improved FEV_1 in the IMT group compared to the control group -For diaphragmatic mobility no significant differences observed in in both groups
Edwards et al. (2016) [17]	55%	Two sets of 30 repetitions every day for 4 weeks.	Placebo followed the same IMT protocol but with 10% MIP	RMS, pulmonary function and (6MWT, VO_2)	-For the experimental group, the MIP and 6-minute walking distance improved significantly from baseline to post-training -For the placebo group, no significant change was observed in the MIP and distance for the 6 MWT -The lung function and VO_2 max did not significantly change in both groups
Kuo et al. (2020) [16]	55%	30 breath training sessions for 6 weeks, 3 days per week and twice per day	Placebo followed the same IMT protocol but with 10% MIP	MIP, pulmonary function test and 6 MWT	-PI max showed a significant difference in the IRT group, and it was significantly higher than that of the PLA group There were also significant differences in PI max before and after the test in the IRT group, where there were no significant differences before and after the test in the PLA group. -The pulmonary function test did not significantly differ between the IRT and PLA groups. -For 6MWT, the walking distance of the IRT group was significantly greater than that of the PLA group. Additionally, the difference was significant between the pre- and post-training conditions in the IRT group
Ponde et al. (2021) [8]	40-80%	Five sessions every week for six weeks (*)	Group B There was no inspiratory muscle training, only aerobic exercise	PI max pre and post for both groups 6 min walk distance pre and post for both groups. VO_2 pre and post for both groups Compare 6 MWT, PI max and VO_2 between Group A and Group B	-Significant improvements were observed for the 6 min walk distance and PI max in group A before and after treatment, whereas VO_2 did not display any difference -There was no significant difference before and after treatment conditions in group B for 6 MWT, PI max and VO_2 Group A exhibited significant improvements for 6 min walk distance, PI max and VO_2 when compared with group B

IMT: Inspiratory training device; RMS: Respiratory Muscle Strength; 6MWT: 6 minute Walking Test; VO_2: Peak Oxygen Consumption; EXP: Experimental group; MVV: Maximum Voluntary Ventilation; FEV1: Forced Expiratory Volume in first second; FVC: Forced Vital Capacity; FIV1: Forced Inspiratory Volume; PIMax: Maximum Inspiratory pressure; MIP: Maximum Inspiratory Pressure; PLA: Placebo group; IRT: Inspiratory Resistive Training; (*) The initial load was at 40% of the subject's baseline for 7 minutes, with a frequency of 3 sets of 10 breaths and an arrest period of 2 minutes between each set. After the first two weeks, PI max increased to 60%. After four weeks, PI max increased to 80%. The subjects were asked to perform a 5-minute warm-up exercise consisting of an all-range-of-motion (ROM) and 1 minute of marching. Aerobic exercise of moderate intensity (RPE 11-13) five days per week for six weeks.

Participants

A total of 184 participants were included in the selected five studies: 96 received IMT intervention and 88 were controls. The studies involved males and females who were obese or overweight with a BMI starting from 23 kg/m^2 to 45.6 kg/m^2. Their mean ages ranged from 22.87±3.85 to 55±11.0. Two studies did not report on their participants' gender distribution [3, 8].

Characteristics of Training

The duration of the IMT training in all studies varied from 4 weeks to 12 weeks. Fifty-five per cent of the individualised maximal inspiratory effort was the most common set load, which is used in three studies [7, 16, 17]. One study used a 30% load of the maximal inspiratory effort [3]. In another study, the initial training load was 40%, but the load was increased to 60% after two weeks and to 80% of the participants' baseline maximal inspiratory pressure after four weeks [8]. Three studies depended on time as a training protocol [3, 7, 17], and two used repetitions as a training protocol [8, 16]. The frequency varied across the five studies. Two studies involved two sets of 30 repetitions over four weeks, twice a day weekly [7, 17]. One study used a protocol of 30 minutes per day, divided into two 15-minute sessions, at a frequency of five times weekly for 12 weeks [3]. In another study, 30 breath training sessions were held twice daily at a frequency of three days per week for six weeks [16].

The most recent study involved three sets of 10 breaths with an arrest of two minutes after each set at a frequency of five 7-minute weekly sessions for six weeks [8]. The participants performed a five-minute warm-up followed by moderate-intensity aerobic exercise (walking), as indicated by (Borg RPE 11–13). In the first two weeks, participants walked for 20 minutes. This period was increased to 30 minutes in the third and fourth weeks and 40 minutes in the final two weeks. Participants engaged in a cooldown period of five minutes. The control group performed only aerobic exercise without IMT training. In the other four studies, the control group received IMT with a minimal load of 10 cmH2O, which had no effect [3, 7, 16, 17].

Outcomes

Maximum inspiratory pressure and endurance

All studies assessed respiratory muscle strength using the maximum inspiratory pressure (MIP), which was the primary outcome in all the studies. These studies demonstrated that IMT promoted an increase in participants' MIP after IMT training. Additionally, there was a significant difference in the values of MIP between the control and IMT groups. One study assessed respiratory muscle endurance through maximum voluntary ventilation and found significant changes after IMT interventions for 12 weeks [3].

Diaphragmatic mobility

One study only assessed diaphragmatic mobility using non-invasive ultrasonography and compared the IMT and control groups. The results showed no significant difference between two groups [3].

Functional capacity

A 6-minute walking test and maximum O2 uptake (VO_2) was used to assess the participants' functional capacity across the studies. Four studies identified a significant increase in walking distance after IMT training compared to before IMT training and in comparison to the control group [7, 8, 16, 17]. Three studies assessed VO_2 after IMT training; two found no significant difference in the predicted maximum VO_2 between the IMT and control groups [7, 17], while one found significant improvements in VO_2 only in the IMT group [8].

Lung function

Four studies were conducted to assess the lung function variables. Only one study found a significant increase in FEV_1 in the IMT group [3]. Three studies demonstrated no significant change in lung function after IMT training in either group [7, 16, 17].

Methodological Quality

Figure 2 and **Figure 3** presents the quality of the methods for the five studies using the RoB 2.0 scale. Three studies were categorised as low risk [3, 7, 17]. Two studies did not provide information about the assessor's blinding and were therefore classified in the 'some concern' category [8, 16].

DISCUSSION

This systematic review investigated the effects of IMT on inspiratory muscle strength and functional capacity in obese and overweight participants through many outcome measures. The results indicate that IMT training increase the strength of the respiratory muscles by improving MIP, as assessed in all five studies [3, 7, 8, 16, 17], endurance, which was measured by maximum voluntary ventilation (MVV), as observed in one study [3].

The findings of the current systematic review agree with the findings of Caicedo-Trujillo et al. [18] and Padula et al. [21]. In these studies, the authors concluded that IMT improved the MIP despite variations in the frequency and duration of the intervention [18, 21]. These impartments may be physiologically due to IMT training may increase the size of type II muscle fibres and enhance the development of diaphragm hypertrophy, which in turn increases the strength of the inspiratory muscle [22].

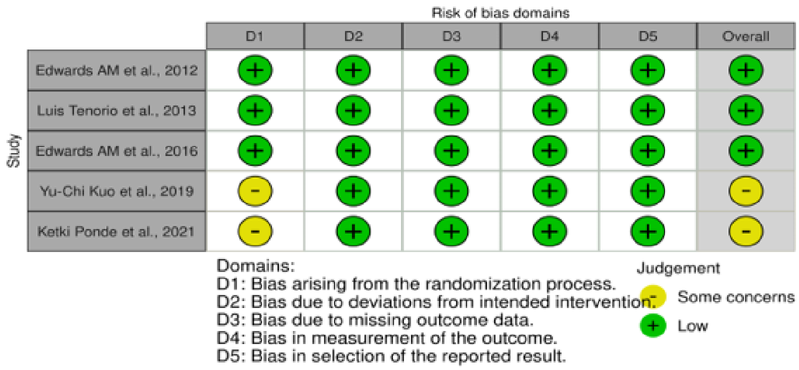

Figure 2. Risk of bias assessment of the included studies (Source: Authors' own elaboration)

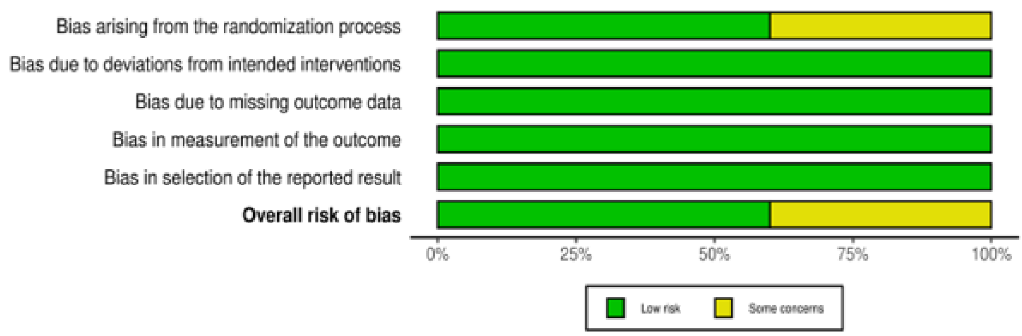

Figure 3. Risk of bias as percentage (RoB 2) (Source: Authors' own elaboration)

In one study, respiratory muscle endurance was assessed by maximum voluntary ventilation (MVV), which showed significant improvement. The authors determined similar increases in MVV in their previous studies [9, 23]. Respiratory muscle endurance is expected to decrease in obese individuals because of the accumulation of fatty tissue on the abdomen, which is associated with a higher workload on the respiratory system. The use of IMT helps obese individuals to reduce their workload and oxygen consumption [24].

Only one study assessed diaphragmatic mobility in obese participants and noted no change after IMT training [3]. However, during the assessment of diaphragmatic motion by ultrasonography, the participants were in supine position, which might be the cause of no improvement in diaphragmatic mobility [3]. When obese individuals are supine, the diaphragmatic muscles are overstretched, and the MIP is reduced by 50%, which decreases their capacity to create strength [3]. Furthermore, obese individuals suffer from an accumulation of body fat in the abdomen, which reduces the efficiency and mobility of the diaphragm [25]. The current results are supported with the findings of the study which assessed the diaphragm using thoracic radiography and they found non- significant changes in diaphragmatic in patients with diabetes [26].

Improved respiratory muscle strength is expected to increase respiratory capacity by enhancing muscle oxygenation and diminishing respiratory muscle fatigue, thus leading to improved cardiopulmonary functional capacity [27, 28]. Functional capacity was assessed by a 6-minute walking test and VO_2. In four studies, the walking distance increased after IMT training because of increased the strength of the respiratory muscles [7, 8, 16, 17]. Improving the strength of respiratory muscles enhances the ventilatory capacity, which allows patients to walk more [29]. Increases in the strength of the respiratory muscles positively affect respiratory capacity by improving muscle oxygenation, lowering muscle lactate production, and ultimately diminishing muscle fatigue, which leads to higher functional fitness [22].

To evaluate functional capacity, the authors in three studies assessed predicted VO_2 after IMT training [7, 8, 17]. It was found non-significant difference of the predicted VO2 between IMT and control groups [7, 17], while a significant improvement in VO_2 was determined in one study between the IMT and control groups [8]. This may be explained to the authors applied aerobic exercise in addition IMT training for the IMT group while aerobic exercise applied only for the control group. Aerobic exercise increases the aerobic enzyme level, enhancing respiratory capacity and improving cardiac output, improving pulmonary diffusion capacity and the alveolar ventilation-to-perfusion ratio. An increase in O2 utilisation by working muscle improves its efficiency. Additionally, increases in muscle myoglobin content cause an increased rate of oxygen transport and the rate of oxygen diffusion to mitochondria. Increasing the lactate threshold at a sub-maximal workload improves the muscles' metabolic function [30, 31]. In three studies, non-significant changes was determined in the lung functions [7, 17], which were consistent with the findings of other studies testing IMT under different conditions [31-33].

Only one study, which applied IMT training for 12 weeks, the author found improvement in FEV_1 in the IMT group [3], where the FEV_1 is an essential parameter for assessing extra-thoracic airway obstruction [34]. Airway obstruction in obese individuals occurs because of fat deposits in the thoracic cage and the neck area, causing a decrease in chest wall compliance as well as a decrease in the size of the central airways, resulting in a decrease in FEV_1 [35]. It is essential to highlight that patients with obesity may develop restrictive disorders [36]. Mechanical compression occurs because of obesity in the diaphragm and thoracic cavity, which reduces respiratory muscle strength [37]. The effect of IMT was characterised with increases in the values of the MIP, and it is expected that the pressure gain positively impacts the decreasing airway resistance in obese individuals [3]. This systematic review has many strengths. This is the first systematic review in healthy, overweight and obese adults using functional outcomes that is usually associated with mortality and morbidity. This study looked at all available publications from 2012 until 2023. Additionally, the systematic review strictly followed PRISMA guidelines.

Limitations

This systematic review has some limitations. First, only five studies were included in this review, and these studies did not specify the severity of obesity among the participants. Second, all the included studies were having a small sample size. Third, there are considerable variations in the protocol of the interventions used in the selected studies. Finally, the methodological quality of two of the studies is questionable since they did not mention the randomisation method.

CONCLUSION

IMT improves inspiratory muscle strength and functional capacity in obese and overweight adult individuals. Healthcare professionals should consider including IMT to any prescribed rehabilitation program particularly for those with obese and overweight. At the same time further studies with more randomized control trials are needed to determine the best protocol for using IMT with healthy overweight and obese individuals.

Author contributions: MMA: conceptualization, methodology, literature search, writing - original draft, study screening, bias assessment, data analysis; **SN:** methodology, data analysis, writing - review & editing; **MA:** conceptulalization, writing - review & editing; **MEA:** project supervision, writing - review & editing; **SA:** study screening, data extraction, risk of bias assessment, data analysis; **HJA:** writing - review & editing; **AS:** project supervision, writing - review & editing. All authors have agreed with the results and conclusions.

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Ethical statement: The authors stated that the study is a systematic review of previously published research. The study did not involve human participants, animals, or identifiable personal data. Therefore, no ethical approval was required.

AI statement: The authors stated that no artificial intelligence (AI) tools were used in the preparation, writing, or editing of this manuscript.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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