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[Intervention Review]

Inspiratory muscle training for asthma

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ABSTRACT

Background

In some people with asthma, expiratory airflow limitation, premature closure of small airways, activity of inspiratory muscles at the end of expiration and reduced pulmonary compliance may lead to lung hyperinflation. With the increase in lung volume, chest wall geometry is modified, shortening the inspiratory muscles and leaving them at a sub-optimal position in their length-tension relationship. Thus, the capacity of these muscles to generate tension is reduced. An increase in cross-sectional area of the inspiratory muscles caused by hypertrophy could offset the functional weakening induced by hyperinflation. Previous studies have shown that inspiratory muscle training promotes diaphragm hypertrophy in healthy people and patients with chronic heart failure, and increases the proportion of type I fibres and the size of type II fibres of the external intercostal muscles in patients with chronic obstructive pulmonary disease. However, its effects on clinical outcomes in patients with asthma are unclear.

Objectives

To evaluate the efficacy of inspiratory muscle training with either an external resistive device or threshold loading in people with asthma.

Search methods

We searched the Cochrane Airways Group Specialised Register of trials, Cochrane Central Register of Controlled Trials (CENTRAL), ClinicalTrials.gov and reference lists of included studies. The latest search was performed in November 2012.

Selection criteria

We included randomised controlled trials that involved the use of an external inspiratory muscle training device versus a control (sham or no inspiratory training device) in people with stable asthma.

Data collection and analysis

We used standard methodological procedures expected by The Cochrane Collaboration.

Main results

We included five studies involving 113 adults. Participants in four studies had mild to moderate asthma and the fifth study included participants independent of their asthma severity. There were substantial differences between the studies, including the training protocol, duration of training sessions (10 to 30 minutes) and duration of the intervention (3 to 25 weeks). Three clinical trials were produced by the same research group. Risk of bias in the included studies was difficult to ascertain accurately due to poor reporting of methods.

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The included studies showed a statistically significant increase in inspiratory muscle strength, measured by maximal inspiratory pressure (P_{Imax}) (mean difference (MD) 13.34 cmH₂O, 95% CI 4.70 to 21.98, 4 studies, 84 participants, low quality evidence). Our other primary outcome, exacerbations requiring a course of oral or inhaled corticosteroids or emergency department visits, was not reported. For the secondary outcomes, results from one trial showed no statistically significant difference between the inspiratory muscle training group and the control group for maximal expiratory pressure, peak expiratory flow rate, forced expiratory volume in one second, forced vital capacity, sensation of dyspnoea and use of beta₂-agonist. There were no studies describing inspiratory muscle endurance, hospital admissions or days off work or school.

Authors' conclusions

There is no conclusive evidence in this review to support or refute inspiratory muscle training for asthma. The evidence was limited by the small number of trials with few participants together with the risk of bias. More well conducted randomised controlled trials are needed. Future trials should investigate the following outcomes: lung function, exacerbation rate, asthma symptoms, hospital admissions, use of medications and days off work or school. Inspiratory muscle training should also be assessed in people with more severe asthma and conducted in children with asthma.

PLAIN LANGUAGE SUMMARY

Inspiratory muscle training for asthma

Review question

We wanted to find out if inspiratory muscle training (IMT) using an external resistive device is better than no treatment (or usual care) in people with chronic asthma. An external resistive device is something that makes it harder for the patient to breathe in. The idea is that doing breathing exercises with a device that makes it harder to breathe in helps to strengthen the muscles of respiration (for example like lifting a weight) and strengthens the muscles that pump air into the lungs. This would make it easier for the person to breathe during day-to-day life. This review aimed to explore the effect of IMT in asthma.

Background

Asthma is the most common chronic disease found in children and young adults. Clinically, asthma is characterized by symptoms of shortness of breath, wheeze and cough, and episodes of worsening of symptoms. The objective of asthma treatment is to achieve and maintain control of the disease and to reduce symptoms. In most cases the symptoms can be controlled with inhalers, but IMT may assist treatment. For people with other chronic respiratory diseases, IMT significantly increases the strength of the inspiratory muscles, reduces dyspnoea and improves quality of life. It is unclear whether inspiratory muscle training has similar benefits in individuals with asthma.

Study characteristics

We found and included five studies in our review. Three studies were conducted by the same group of researchers in Israel ([Weiner 2000](#); [Weiner 2002](#); [Weiner 2002a](#)), one study ([Sampaio 2002](#)) was conducted in Brazil and one trial was conducted in the United Kingdom ([McConnell 1998](#)). A total of 113 adults with asthma (46 male and 67 female) were included. No study included children.

Key results

The studies showed a significant improvement in inspiratory muscle strength (P_{Imax}). People with asthma who received IMT on average increased their inspiratory muscle strength, but it was not possible to state whether this improvement seen in inspiratory muscle strength translated into any clinical benefit. Results from one study showed no significant difference between the training group and the control group (no treatment or usual care) for expiratory muscle strength, lung function, sensation of dyspnoea (breathlessness) and use of reliever medication. There were no studies describing exacerbation events that required use of reliever medication or emergency department visits, inspiratory muscle endurance, hospital admissions and days off work or school. Given the insufficient evidence found in this review, we believe that there is a need for more well conducted studies in order to assess the efficacy of IMT in people with asthma, including children.

Quality of the evidence

There were substantial differences between the studies, including the training protocol, duration of training sessions (10 to 30 minutes) and duration of the intervention (over 3 to 25 weeks). The methodological quality of the studies included in this update was difficult to accurately ascertain. Study samples were small and the risk of bias was mostly unclear, due to inadequate reporting. Overall the quality of the evidence included in the review was very low. This summary was current to November 2012.

SUMMARY OF FINDINGS

Summary of findings for the main comparison. Inspiratory muscle training versus control for asthma

Inspiratory muscle training versus control for asthma

Patient or population: Participants with asthma

Settings: Three countries (United Kingdom, Brazil and Israel)

Intervention: Inspiratory muscle training versus control

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of Participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Control	Inspiratory muscle training versus Control				
Inspiratory muscle strength (PImax; cmH ₂ O) Follow-up: mean 3 to 25 weeks	The mean PImax ranged across control groups from 78.70 to 121.7 cmH₂O	The mean PImax in the intervention groups was 13.34 higher (4.7 to 21.98 higher)		84 (4 studies)	⊕⊕⊕⊕ low 1,2	Fixed effects I ² =43%
Exacerbations requiring a course of oral or inhaled corticosteroids or emergency department visits	See comment	See comment	See comment	See comment		Not reported
PEmax cmH ₂ O Follow-up: 3 to 6 weeks	The mean PEmax ranged across control groups from 78.8 to 152.8 cmH₂O	The mean PEmax in the intervention groups was 14.46 higher (2.93 lower to 31.84 higher)		38 (2 studies)	⊕⊕⊕⊕ very low 1,2,3	Fixed effects I ² =54%
FEV1 (actual values at end of intervention) L	See comment	See comment	Not estimable	18 (1 study)	⊕⊕⊕⊕ very low 4	There was only one trial contributing to this outcome so we were unable to pool

Follow-up: 3 weeks						
Dyspnoea	See comment	See comment	Not estimable	18 (1 study)	⊕⊕⊕⊕ very low ⁴	There was only one trial contributing to this outcome so we were unable to pool
Measured using Borg scale						
Follow-up: 3 weeks						
Use of beta₂-agonist	See comment	See comment	Not estimable	22 (1 study)	⊕⊕⊕⊕ very low ⁴	There was only one trial contributing to this outcome so we were unable to pool
Puffs per day						
Follow-up: 3 months						

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

¹ Although McConnell was a quasi-randomised trial at high risk of selection bias, removing this study in a sensitivity analysis did not have a significant impact on the direction, size or uncertainty of the treatment effect. We downgraded for risk of bias due to lack of clear reporting on all aspects of study design for the studies.

² Wide confidence intervals. The confidence interval was wide in all included studies, due to the sample size and standard deviation of measurements across individuals.

³ Few participants in few studies.

⁴ Single study.

BACKGROUND

Description of the condition

Asthma is considered a serious public health problem worldwide, being the most common chronic disease found in children and young adults (To 2012). The incidence of asthma has increased during the last three decades, especially in industrialized countries, and is associated with large healthcare costs (Zhang 2010).

Asthma is a chronic inflammatory disease of the airways characterized by variable airflow limitation and airway hyper-responsiveness (Bourdin 2012; Gershon 2012). Its symptoms include breathlessness, wheeze and cough together with episodes of exacerbations (Brightling 2012). Asthma is characterized by a variability of signs and symptoms over time. Its natural history includes persistent chronic inflammation and structural alterations in the lungs that may be associated with persistent symptoms and reduction of lung function, and it is commonly associated with acute episodes of deterioration (Reddel 2009).

Since asthma is not curable, the objective of asthma management is to achieve and maintain control of the disease and to ameliorate symptoms. The treatment aims to ensure control of the clinical manifestations and to control the expected future risk (exacerbations, accelerated decline in lung function, and side effects of treatment) (GINA 2011). In most people, clinical control of asthma can be achieved with a proper pharmacological treatment (Bassler 2010; Bateman 2008). However, therapy such as pulmonary rehabilitation (Ochmann 2012) and inspiratory muscle training (Turner 2011) may also be beneficial in asthma, by improvement of functional capacity and a reduction in dyspnoea and healthcare services use.

Description of the intervention

The inspiratory muscles are morphologically and functionally skeletal muscles and therefore respond to training, just as any muscle of the locomotor system (Romer 2003). Inspiratory muscle training (IMT) is a technique used to increase strength or endurance of the diaphragm and accessory muscles of inspiration (Illi 2012).

There are three types of IMT, normocapnic hyperpnoea, flow resistive loading and pressure threshold loading. "Normocapnic hyperpnoea is a training approach that requires people to ventilate at a high proportion of their maximum voluntary ventilation for a fixed period using complicated rebreathing circuitry to ensure stable levels of carbon dioxide" (Hill 2010). It has not been used frequently in patients because it requires specific and complicated equipment to prevent hypocapnia (Scherer 2000) and, furthermore, it is very strenuous exercise.

Normocapnic hyperpnoea corresponds to endurance training because it involves high flow and low pressure. In normocapnic hypopnoea training, the inspiratory and expiratory muscles are recruited. Flow resistive loading and pressure threshold loading cause specific recruitment of the inspiratory musculature and promote strength training (Romer 2003).

In flow resistive loading, the individual breathes via a device with a variable-diameter orifice. Thus, for a given airflow, the smaller the orifice the greater the load achieved. In this type of training the inspiratory pressure, and consequently the training load, varies with flow rate according to the orifice size. Therefore, it is essential

that the individual respiratory pattern be monitored during the training to ensure an adequate training load (McConnell 2005a).

In threshold loading a device that contains a one-way valve is used. This valve remains closed at the beginning of inspiration and the individual breathes against the spring-loaded valve until enough pressure is generated to release the resistance and allow flow. At expiration, the one-way valve opens and no resistance is imposed on this phase of breathing (McConnell 2005a). The user experiences a predetermined and constant pressure independent of breathing pattern or flow (Hill 2004; Moodie 2011). Threshold loading is the most widely used IMT method because it is portable and easy to use. However, there are no data to support the superiority of one IMT method over the other in asthma, although they have been compared in a systematic review of IMT in healthy individuals (Illi 2012).

How the intervention might work

In people with asthma there are four mechanisms leading to lung hyperinflation. These are expiratory airflow limitation; premature closure of the small airways; activity of the inspiratory muscles at the end of expiration; and reduced pulmonary compliance (Burgel 2009). With the increase in lung volume, the chest wall geometry is modified, shortening the inspiratory muscles and leaving them at a sub-optimal position in the length-tension relationship (Clanton 2009; Lopes 2007).

The reduction of force generated by the inspiratory muscles necessitates an increase in respiratory drive (Huang 2011; McConnell 2005). However, the increase of the maximal inspiratory pressure (P_{Imax}) resulting from the IMT may significantly reduce the inspiratory motor drive (Huang 2003), probably due to a decrease in the number of motor units recruited during breathing, with consequent reduction in the sensation of dyspnoea.

IMT can in some cases promote diaphragm hypertrophy (Chiappa 2008; Downey 2007; Enright 2006) and increase the proportion of type I fibres and the size of the type II fibres of the external intercostal muscles (Ramirez-Sarmiento 2002). The force generated by skeletal muscles depends on the effective cross-sectional area. Therefore, the increase in cross-sectional area of the inspiratory muscles caused by hypertrophy could reverse or delay the deterioration of inspiratory muscle function (Enright 2004). Nevertheless, a variety of factors can affect the efficacy of IMT, including the degree of hyperinflation, severity of airway obstruction, and also the frequency and duration of training (Liaw 2011).

Why it is important to do this review

This is an update of a Cochrane Review first published in 2003, which concluded that there was insufficient evidence on the clinical benefits of IMT in individuals with asthma (Ram 2003). However, recent meta-analyses showed that IMT significantly increases the strength and endurance of the inspiratory muscles, reduces dyspnoea and improves exercise capacity and quality of life in people with chronic obstructive pulmonary disease (COPD) (Geddes 2008; Gosselink 2011); and improves endurance exercise performance in healthy individuals (Illi 2012). New clinical trials evaluating the effects of IMT on muscle strength, peak expiratory flow, exercise tolerance and perception of dyspnoea in asthma have been published since the last version

of this review (Lima 2008; Sampaio 2002; Shaw 2011; Turner 2011). Therefore, we conducted this update to incorporate the latest evidence.

OBJECTIVES

To evaluate the efficacy of inspiratory muscle training (IMT) with either an external resistive device or threshold loading in people with asthma.

METHODS

Criteria for considering studies for this review

Types of studies

We included parallel randomised controlled trials (RCTs) that involved the use of an external inspiratory muscle training device versus a control.

Types of participants

People with stable asthma as defined by internationally accepted criteria (for example American Thoracic Society, British Thoracic Society) or objectively defined with a clinical diagnosis of asthma.

Types of interventions

The IMT modalities under consideration were flow resistive loading and threshold loading. We excluded trials that had mixed interventions (for example IMT plus breathing exercises). We included control groups that received either sham IMT, no intervention or different intensities of IMT.

Types of outcome measures

Primary outcomes

1. Inspiratory muscle strength
2. Exacerbations requiring a course of oral or inhaled corticosteroids or emergency department visits

Secondary outcomes

1. Inspiratory muscle endurance
2. Expiratory muscle strength
3. Lung function
4. Asthma symptoms (e.g. measures of dyspnoea or breathlessness with Borg score or a Visual Analogue Scale (VAS))
5. Hospital admissions
6. Use of reliever medication
7. Days off work or school

Search methods for identification of studies

Electronic searches

We identified trials from the following sources:

1. Cochrane Airways Group Specialised Register of trials (CAGR), which is derived from systematic searches of bibliographic databases and handsearching of respiratory journals and meeting abstracts (see Appendix 1);
2. Cochrane Central Register of Controlled Trials (CENTRAL) in *The Cochrane Library* (2012, Issue 11 of 12);
3. ClinicalTrials.gov.

Databases were searched from their inception and there was no restriction on the language of publication. See Appendix 2 for the full search strategies.

Searching other resources

We checked reference lists of all primary studies and review articles for additional references. We contacted the authors of trials that were included and asked them to identify other published and unpublished studies.

Data collection and analysis

Selection of studies

Two review authors (ISS and CTDR) independently reviewed all abstracts retrieved. Agreement between review authors was reported and any disagreements were resolved by discussion. We obtained the full texts of all papers considered relevant based on the review of their titles and abstracts and two review authors independently evaluated each against the inclusion criteria.

Data extraction and management

Two review authors (ISS and GAFF) independently extracted data using a data collection form. Whenever possible, we contacted the author of each included controlled trial to verify the accuracy of the extracted data and to obtain further data or information.

Assessment of risk of bias in included studies

Two review authors (ISS and CTDR) independently assessed risk of bias for each study using the Cochrane Collaboration's 'Risk of bias' tool, according to the following domains:

1. random sequence generation;
2. allocation concealment;
3. blinding of participants and personnel;
4. blinding of outcome assessment;
5. incomplete outcome data;
6. selective reporting;
7. other bias.

We graded each potential source of bias as high, low or unclear risk of bias. Any disagreements were resolved by discussion involving the third assessor (GMHF).

Measures of treatment effect

Continuous outcomes were expressed as mean difference (MD) or as standardised mean difference (SMD) if different methods of measurement were used by the studies. For dichotomous outcomes, we used the risk ratio (RR).

Unit of analysis issues

The unit of analysis was the patient.

Dealing with missing data

We contacted the original investigators to verify key study characteristics and to request missing data.

Assessment of heterogeneity

We tested heterogeneity between comparable studies using a standard χ^2 test. In addition, we used the value of the I^2 statistic to assist in determining levels of heterogeneity.

Assessment of reporting biases

We planned to assess potential reporting biases through visual inspection of a funnel plot if we were able to pool 10 or more studies in one meta-analysis. In instances of less than 10 studies, we extrapolated on reporting biases within the 'other bias' section in the risk of bias tables.

Data synthesis

We used the fixed-effect model for meta-analysis.

Subgroup analysis and investigation of heterogeneity

We planned the following subgroups:

- duration of intervention (less than eight weeks or eight weeks or more);
- resistance of IMT device (percentages analysed together);
- intensity of IMT training (strength or endurance).

Sensitivity analysis

We planned to perform sensitivity analysis on the reported methodological quality of trials (high versus unclear versus low risk of bias).

RESULTS

Description of studies

Results of the search

For the previous version of this review, searches were conducted up to April 2003. For this update, the search was amended and run across all years up to 23 November 2012. We identified 127 references for possible inclusion in the review. After adjusting for duplicates 97 remained. From these, two review authors selected 11 abstracts as possibly being appropriate for inclusion in the review. We identified six additional references by searching the bibliographies of the retrieved studies. Therefore, we retrieved a total of 17 full text papers for possible inclusion. After reading the full texts of these 17 studies, we excluded 12 as not appropriate. Five trials fulfilled the inclusion criteria and were included in this review. A PRISMA diagram can be found in [Figure 1](#).

Figure 1. Study flow diagram.

Included studies

The five trials were published between 1998 and 2002. Four studies were included from the original review and one additional study which met the inclusion criteria was identified for this update (Sampaio 2002). Three of the included RCTs were conducted by the same group of researchers in Israel and had similar study designs (Weiner 2000; Weiner 2002; Weiner 2002a). One study (Sampaio

2002) was conducted in Brazil and was published in a non-English language journal. One study was conducted in the United Kingdom and was published only as an abstract (McConnell 1998) therefore it was devoid of the full details. Completed details of all five included studies are provided in the [Characteristics of included studies](#) table. Below is a brief summary of the five included studies. We have written to all authors for further information.

Design

Three were double-blind (assessors and participants) randomised controlled trials and all had run-in phases that varied from two to four weeks ([Weiner 2000](#); [Weiner 2002](#); [Weiner 2002a](#)). One was a single-blind (participants) randomised controlled trial without a run-in phase ([McConnell 1998](#)). [Sampaio 2002](#) was a randomised controlled single-blind (assessors) trial and had a one month post-intervention phase (follow-up).

Participants

Five studies involving 113 people with asthma (46 male and 67 female) met the inclusion criteria. Ten participants dropped out of the studies, so the results of the remaining 103 participants are reported. The sample size of the included studies varied from 18 to 30 adult participants. One study only included participants who had 'high consumption' of bronchodilators, defined as greater than one puff of beta₂-agonist per day ([Weiner 2000](#)). [Weiner 2002a](#) only recruited female participants.

The criteria for a diagnosis of asthma were provided in all included studies. Three trials diagnosed asthma according to the American Thoracic Society (ATS) criteria and in one trial asthma was defined by a clinical diagnosis ([Sampaio 2002](#)). In one study ([McConnell 1998](#)) diagnosis of asthma was made by a consultant chest physician on the basis of spirometry, examination and history.

Four studies included participants with mild to moderate asthma: [McConnell 1998](#) stated mild to moderate; [Weiner 2000](#) enrolled participants with forced expiratory volume in one second (FEV₁) > 80% predicted; [Weiner 2002](#) and [Weiner 2002a](#) had participants with FEV₁ > 60% predicted. [Sampaio 2002](#) included participants independent of the asthma severity.

Interventions

In [McConnell 1998](#), the IMT group used a protocol with 30 breaths at 50% of P_{Imax} twice daily, whilst the control group trained with 60 breaths at around 20% P_{Imax} twice daily. The duration of the intervention was three weeks in both groups.

The intervention group in [Sampaio 2002](#) trained three times a week over a period of six weeks: 10 minutes each session with resistance

equal to 40% of their P_{Imax} obtained at a daily assessment. The control group received respiratory physiotherapy (especially bronchial hygiene techniques) based on clinical necessity. [Sampaio 2002](#) also included a third intervention arm where participants received physical training in addition to IMT. This intervention was beyond the scope of our review.

Three studies had similar interventions which compared the IMT group to a sham training (control) group ([Weiner 2000](#); [Weiner 2002](#); [Weiner 2002a](#)). Both groups trained once per day, six times a week, 30 minutes each session. The intervention group started breathing at loads equal to 15% of their P_{Imax} for one week. The load was then incrementally increased by 5% to 10% at each session to reach 60% of their P_{Imax} at the end of the first month. The intervention was continued at 60% of P_{Imax} up to the end of the training period. Load level was adjusted every week according to the participant's new P_{Imax} level. Control group participants trained using the same training device but with no resistance. The duration of the intervention varied between studies. In the [Weiner 2000](#) trial both groups trained for a period of three months. The [Weiner 2002](#) study had a 12 week intervention phase for the control group, and the intervention group continued with the training for as long as it took for the inspiratory muscle strength to increase by more than 20 cmH₂O over their baseline value (within 16 to 25 weeks). In [Weiner 2002a](#), the endpoint of the training was designed to be when the mean inspiratory muscle strength of the women in the training group equalled that of the males with asthma (which took approximately 20 weeks).

Excluded studies

Twelve studies were excluded and the reasons for exclusion of these studies are listed in the [Characteristics of excluded studies](#) table. One trial ([Weiner 1992](#)) that was previously included in review was excluded as it was a double-blind comparative trial and randomisation was not conducted.

Risk of bias in included studies

Assessment of risk of bias was difficult due to poor reporting of methods in the trials. See the 'Risk of bias' tables (in [Characteristics of included studies](#)) for further information and [Figure 2](#).

Figure 2. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
McConnell 1998	+	?	+	+	+	+	?
Sampaio 2002	?	?	+	+	+	+	?
Weiner 2000	?	?	+	+	+	?	?
Weiner 2002	?	?	+	+	+	?	+
Weiner 2002a	?	?	+	+	+	?	+

Allocation

All included studies were described as randomised. Upon correspondence, [McConnell 1998](#) provided us with the methods of sequence generation, which indicated that the trial was quasi-randomised having ranked participants according to their forced vital capacity (FVC) and then allocated them to treatment group using alternation. We therefore judged [McConnell 1998](#) to have a high risk of bias, while the remaining four trials were unclear. No study reported sufficient detail about the allocation concealment. Thus, we judged all studies to be at unclear risk of bias for allocation concealment.

Blinding

Three studies were described as double-blind (assessors and participants) and were judged to be at low risk of performance bias and detection bias ([Weiner 2000](#); [Weiner 2002](#); [Weiner 2002a](#)). One trial ([McConnell 1998](#)) mentioned only blinding of participants and was judged to be at low risk of performance bias and high risk of detection bias. The [Sampaio 2002](#) study conducted blinding of data assessors only, so we judged it to be at high risk of performance bias and low risk of detection bias.

Incomplete outcome data

Incomplete outcome reporting of data was evident in one study (Weiner 2002), which we judged to be at high risk of bias. In one study the dropouts were balanced between arms, but we were unsure if this study was biased (Weiner 2002a). The remaining trials were judged to be at low risk of bias as there were no withdrawals.

Selective reporting

Three studies either reported insufficient data or data in a format unsuitable for meta-analysis, however we could not be sure whether this represented a risk of bias (Weiner 2000; Weiner 2002; Weiner 2002a). The remaining two studies documented findings for all pre-specified outcomes, therefore we judged them as at low risk of selective reporting. McConnell 1998 and Sampaio 2002 contained insufficient details to be able to make judgments on the risk of bias, but the authors provided all the numerical data on request.

Other potential sources of bias

The length of the interventions, and therefore the time points for outcome assessment, were variable in two trials (Weiner 2002;

Weiner 2002a). Therefore we judged them as high risk of bias. We could not be sure whether there were any other potential biases in the remaining studies, and we therefore judged them to be at unclear risk of bias.

Effects of interventions

See: **Summary of findings for the main comparison** Inspiratory muscle training versus control for asthma

Primary outcome: inspiratory muscle strength

All included studies measured inspiratory muscle strength. Four studies (McConnell 1998; Sampaio 2002; Weiner 2000; Weiner 2002) involving 84 participants were included in the meta-analysis, which demonstrated a statistically significant increase in PImax (MD 13.34 cmH₂O, 95% CI 4.70 to 21.98; Analysis 1.1; Figure 3), although the confidence intervals were wide. There was no significant heterogeneity ($I^2 = 43\%$, $P = 0.16$). The random-effects model showed similar results (MD 12.62 cmH₂O, 95% CI 1.00 to 24.23, $I^2 = 43\%$, $P = 0.16$).

Figure 3. Forest plot of comparison: 1 Inspiratory muscle training versus Control, outcome: 1.1 PImax - cmH₂O.

Weiner 2002a did not report the data for the control group, therefore it could not be entered in the meta-analysis.

Primary outcome: exacerbations requiring a course of oral or inhaled corticosteroids or emergency department visits

These outcomes were not reported.

Secondary outcome: expiratory muscle strength

Two studies involving 38 participants looked at maximal expiratory pressure (PEmax). Overall there was no statistically significant difference between the IMT and control groups for this outcome (MD 14.46, 95% CI -2.93 to 31.84; Analysis 1.2) and no significant heterogeneity between studies ($I^2 = 54\%$, $P = 0.14$), though the trials reported conflicting results. The Sampaio 2002 trial showed a statistically significant increase in this outcome for the IMT group compared with control, whereas in McConnell 1998 IMT did not increase the PEmax.

Secondary outcome: lung function

A single trial (McConnell 1998) assessed peak expiratory flow rate (PEFR), forced expiratory volume in one second (FEV1) and forced vital capacity (FVC). All these outcomes were not significantly different compared to the control group.

Secondary outcome: asthma symptoms

Four studies involving 83 participants measured the sensation of dyspnoea using a modified Borg scale. In three studies involving 65 participants (Weiner 2000; Weiner 2002; Weiner 2002a) the sensation of dyspnoea was measured while the participant breathed against progressive resistance. McConnell 1998 measured dyspnoea during an incremental cycle test to volitional fatigue. In three studies (Weiner 2000; Weiner 2002; Weiner 2002a) the increase in PImax was associated with a statistically significant decrease in the mean Borg score ($P < 0.05$) in the study group but not in the control group. However, the studies did not report a between-group analysis, and thus the data could not be meta-analysed. Only one trial (McConnell 1998) reported the numerical data and the results showed no significant difference between the two study groups ($P = 0.56$).

Secondary outcome: use of reliever medication

Three trials (Weiner 2000; Weiner 2002; Weiner 2002a) measured daily beta₂-agonist consumption and reported that the training group significantly decreased the use of this drug. However, the Weiner 2002 and Weiner 2002a studies did not report a between-group analysis. The Weiner 2000 study showed no significant overall difference between the IMT group and the control group regarding the use of beta₂-agonist.

No data were available for the following secondary outcomes: inspiratory muscle endurance, hospital admissions and days off work or school.

DISCUSSION

Summary of main results

This systematic review sought to evaluate the efficacy of inspiratory muscle training (IMT) in people with asthma. For this update, one trial (Weiner 1992) included in the last version was excluded and one additional study (Sampaio 2002) was incorporated in the review. Despite a careful review of the available literature, without language restrictions, only five randomised controlled trials satisfied the inclusion criteria. The number of included studies was low and number of participants (113) was also small, therefore the data for analyses were limited. Moreover, trial data were not always presented in suitable format for meta-analysis.

We found that IMT significantly improved inspiratory muscle strength by a mean of 13 cmH₂O, but the confidence intervals were wide. Because there is no established minimally important difference for P_{Imax}, we are uncertain if this improvement in P_{Imax} translates into any clinical benefit. In the previous version of this review (Ram 2003), three studies (Weiner 1992; Weiner 2000; Weiner 2002) with 76 participants showed improvement in P_{Imax} with IMT when compared to the control group (MD 23.07 cmH₂O, 95% CI 15.65 to 30.50, I² = 38%, P = 0.20). Ram 2003 included the Weiner 1992 trial, which contributed a weight of 53% in the meta-analysis. However, this study was a double-blind comparative trial and because it was not randomised we excluded the study from this update to the systematic review. Non-randomised studies frequently yield larger estimates of effect, which may explain the difference in the magnitude of benefit reported in this review (Odgaard-Jensen 2011).

There was no statistically significant difference between the IMT group and the control group for the outcomes of P_{Emax}, PEFR, FEV₁, FVC, sensation of dyspnoea and use of beta₂-agonist.

Overall completeness and applicability of evidence

Most trials predominantly included adult participants with mild or moderate asthma, therefore the results may not be generalised to children or people with more severe asthma. Furthermore, the findings are specific to the type of training performed. In all included studies the training was conducted through the threshold loading, using the POWERbreathe® or Threshold®IMT, and cannot be extended to flow resistive loading.

The small number of included studies together with the risk of bias make it difficult to draw definitive conclusions about the effect of IMT.

Quality of the evidence

There was substantial heterogeneity between the studies, including control characteristics (sham versus no intervention), training protocol (40% to 60% of P_{Imax}), duration of training sessions (10 to 30 minutes) and duration of the intervention (3 to 25 weeks). Furthermore, the aims of the studies varied from evaluating the relationship with the perception of dyspnoea, inspiratory muscle strength and beta₂-agonist consumption before

and after IMT (Weiner 2002) to investigating the gender differences in inspiratory muscle strength on the perception of dyspnoea (Weiner 2002a). In Weiner 2002 the training was designed to end when the inspiratory muscle strength of each participant increased by more than 20 cmH₂O over the baseline, whereas in Weiner 2002a the endpoint of the training was designed to be when the mean inspiratory muscle strength of the women in the training group equalled the strength of the men with asthma. This resulted in a variable duration of training and outcomes that were measured at many different time points, which may have impacted on the measured outcomes.

With respect to training intensity, it was not possible to identify which load was most effective. In people with COPD, a review has concluded that more research is needed to explore the impact that different training protocols (frequency, intensity and duration of IMT, supervision) may have on outcomes (Geddes 2008). A more recent review observed no dose-response relationship for IMT in people with COPD, probably because the studies included in the meta-analysis were set at an inspiratory load of ≥ 30% P_{Imax} (Gosselink 2011).

The methodological quality of the trials included in this update was difficult to accurately ascertain. Study samples were small and the risk of bias was mostly unclear due to inadequate reporting. Allocation concealment was not described adequately in the studies. Studies in which the allocation concealment is inadequate yield larger estimates of treatment effects (Moher 2010) and trials with inadequate or unclear allocation concealment have been shown to exaggerate intervention effect estimates by approximately 7% (Savović 2012).

Five of our nine pre-specified outcomes (56%) were addressed in the analysis. The McConnell 1998 trial provided the majority of data (four of five outcomes), but this study was at high risk of bias for sequence generation. Moreover, the remaining four trials were judged to be at unclear risk of bias for sequence generation. This bias may have overestimated our results. The intervention effect estimates can be exaggerated by an average of 11% in trials with inadequate or unclear sequence generation (Savović 2012).

The GRADE evidence across the review was low or very low. More research is likely to have an important impact on confidence in the estimate of effect for the outcomes investigated and is likely to change the estimate.

Potential biases in the review process

Despite attempts to apply a systematic process in selecting studies for inclusion or exclusion in this update, the final decisions are subject to a level of interpretation. In order to minimise clinical heterogeneity we excluded the trial that had mixed interventions, inspiratory muscle training and breathing exercises (Lima 2008).

Some data that were said to be recorded in a few of the trials were not reported in sufficient detail to allow meta-analysis. We are uncertain what the impact of this was on the results and conclusions of the review. We tried to minimise possible biases by contacting the authors to verify study characteristics and to request data, but no reply was received.

Agreements and disagreements with other studies or reviews

We found no previous non-Cochrane reviews addressing the efficacy of IMT for asthma. This is an update of a Cochrane review published in 2003 (Ram 2003). Thus the search was amended and run again across all years up to 2012. We incorporated one new study (Sampaio 2002) and the latest Cochrane risk of bias tool. We excluded a study which was incorporated in the previous version of the review because the study was not randomised (Weiner 1992). Despite these differences, in both versions IMT significantly improved inspiratory muscle strength but it was not possible to state if this improvement in inspiratory muscle strength translates into any clinical benefit.

AUTHORS' CONCLUSIONS

Implications for practice

There is no conclusive evidence in this review to support or refute inspiratory muscle training for asthma. The evidence was limited by the small number of included randomised controlled trials, number of participants and the risk of bias. There was also clinical heterogeneity between the trials.

Implications for research

There are few studies available that evaluate the effects of inspiratory muscle training for asthma, thus more randomised controlled trials are needed to draw firm conclusions about the topic. The method utilized in the randomisation and also

concealment of the allocation must be appropriate and clearly described by the authors. Blinding of outcome assessment and, when possible, of the participants must be both implemented and described. If losses occur, the analysis must be by intention to treat, and all the data must be described adequately so that they can be entered in a meta-analysis. The trials should investigate important outcomes including respiratory muscle strength, exacerbation rate, lung function, symptoms, hospital admissions, use of medications and days off work or school. IMT should also be assessed in the context of more severe asthma and conducted in children with asthma in order to be able to generalise the findings. Furthermore, attention must be paid to possible side effects that could appear during training. In particular, trial sample sizes should be determined before the start of such studies and the results should be reported following the CONSORT guidelines.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies [ordered by study ID]

McConnell 1998

Methods	A single-blind (participants) randomised controlled trial. Trial took place in United Kingdom. The trial had a three week intervention (and no run-in phase)
Participants	<p>Participants with diagnosis of asthma was made by a consultant chest physician, on the basis of spirometry and examination/history (from correspondence)</p> <p>All participants had stable, mild/moderate asthma</p> <p>Eighteen subjects (10 male and 8 female) were randomised to two groups:</p> <p>Intervention N = 9 M/F = 5/4</p> <p>Control N = 9 M/F = 5/4</p>
Interventions	<p>The intervention group trained with 30 breaths at 50% P_Imax, twice daily for 3 weeks</p> <p>Control group used a protocol with 60 breaths at ~20% P_Imax, twice daily for 3 weeks</p>
Outcomes	FEV1, FVC, PEF, P _I max, P _E max, exertional dyspnoea using modified Borg scale
Notes	<p>Study only published as an abstract.</p> <p>Author written to for further details. Reply received.</p>

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	<p>Quote (from report): "subjects were randomised to two groups"</p> <p>Quote (from correspondence): "subjects divided into males and females; ranked according to FVC and divided as follows:</p> <p>MALE IMT: subject numbers 1,4,5,8,9 Placebo: subject numbers 2,3,6,7,10</p> <p>FEMALE IMT: subject numbers 1,4,5,8 Placebo: 2,3,6,7"</p> <p>Comment: inadequate sequence generation</p>
Allocation concealment (selection bias)	Unclear risk	No information provided
Blinding of participants and personnel (performance bias) All outcomes	Low risk	<p>Quote (from report): "a single-blind, control design"</p> <p>Comment: blinding of participants was ensured</p>
Blinding of outcome assessment (detection bias) All outcomes	High risk	No blinding and the outcome is likely to be influenced by lack of blinding
Incomplete outcome data (attrition bias) All outcomes	Low risk	Eighteen subjects were randomised and all participants were included in the analysis (from correspondence)
Selective reporting (reporting bias)	Low risk	Data reported for all outcomes (from correspondence)

McConnell 1998 (Continued)

Other bias	Unclear risk	Insufficient information to assess whether an important risk of bias exists
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Sampaio 2002

Methods	A randomised controlled trial and only assessors were blind. Trial took place in Brazil The trial had a six week intervention and one month post-intervention phase (follow-up)
Participants	<p>Participants with a clinical diagnosis of asthma provided by a pneumologist. Subjects with inability to walk due to orthopaedic impairments, respiratory infections immediately before or during the training, and severe heart diseases were excluded from the study.</p> <p>Thirty-seven participants were recruited, but 7 were excluded for not completing all experimental stages. The remaining participants were then randomly divided into 3 groups:</p> <p>G1 (physical training and respiratory muscular training): mean $\pm$ SD N = 10 M/F = 2/8 Mean age = 23.7 $\pm$ 8.2 yrs</p> <p>G2 (respiratory muscular training): mean $\pm$ SD N = 10 M/F = 2/8 Mean age = 21.4 $\pm$ 7.0 yrs N = 10</p> <p>G3 (control): mean $\pm$ SD N = 10</p> <p>M/F = 2/8 Mean age = 23.2 $\pm$ 4.8 yrs</p>
Interventions	<p>The G2 trained 3 times a week, 10 minutes each session, for 6 weeks. The participants trained with resistance equal to 40% of their Pimax, obtained at daily assessment.</p> <p>The participants from G3 had no active treatment and only underwent evaluation and reevaluation. According to the need, participants were subjected to physiotherapy, particularly bronchial hygiene techniques.</p>
Outcomes	Ergometric test: anaerobic threshold, Pimax, PEmax
Notes	Author written to for further details. Reply received.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote (from report): "were randomised in 3 groups". Comment: Insufficient information provided.
Allocation concealment (selection bias)	Unclear risk	No information provided.
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding and the outcome is likely to be influenced by lack of blinding.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote (from correspondence): "only assessment was blind" Comment: blinding of outcome assessment was ensured

Sampaio 2002 (Continued)

Incomplete outcome data (attrition bias) All outcomes	Low risk	Thirty subjects were randomised and all participants were included in the analysis.
Selective reporting (reporting bias)	Low risk	Results for P _I max and P _E max are reported graphically for the control group. The original investigators provided numerical results (through correspondence).
Other bias	Unclear risk	Insufficient information to assess whether an important risk of bias exists.

Weiner 2000

Methods	A double-blind (assessors and participants) randomised controlled trial which took place in Israel The trial had a four week run in period and a three month intervention phase	
Participants	<p>All participants satisfied the American Thoracic Society definition of asthma, with symptoms of episodic wheezing, cough, and shortness of breath responding to bronchodilators and reversible airflow obstruction documented in at least one previous pulmonary function study.</p> <p>Participants had mild, stable asthma (FEV₁ > 80% of predicted normal values on at least two visits). All subjects were in stable clinical condition, and their symptoms were controlled by their primary physicians with beta₂-agonists, only as required.</p> <p>Exclusion criteria: participants with recorded PEF_R less than 80% of their best value were excluded from the study after the four week run-in period.</p> <p>Eighty-two participants (46 male and 36 female) were recruited for the study. Six participants were excluded from the study and the remaining 76 subjects were separated into two groups according to beta₂-agonist consumption.</p> <p>High consumers (mean beta₂-agonist consumption of > 1 puff/d): mean ± SEM M/F = 15/8 Mean Age = 34.0 ± 2.8 yrs</p> <p>Normal consumers (mean beta₂-agonist consumption of ≤ 1 puff/d): mean ± SEM M/F = 27/26 Mean Age = 37.3 ± 3.1 yrs</p> <p>In the second stage of the study, the 23 high consumers were randomised into two groups: Group A (intervention) N = 12 Group B (control) N = 11</p>	
Interventions	<p>Subjects in both groups (A and B) trained daily for a period of 3 months, six times a week, with each session consisting of 30 minutes of training.</p> <p>The intervention group started breathing at a resistance level equal to 15% of their P_Imax for 1 week. The resistance then was increased incrementally, 5 to 10% each session, to reach 60% of their P_Imax at the end of the first month. The training then was continued for the next 2 months at 60% of their P_Imax and was adjusted every week to the new P_Imax achieved.</p> <p>Control group participants trained through the same training device with no resistance.</p>	
Outcomes	FEV ₁ , FVC, PEF _R , P _I max, beta ₂ -agonist consumption, dyspnoea using modified Borg scale	
Notes	<p>In addition to participants who met the criteria for exclusion one patient was dropped from the study group because of the exacerbation in his asthma. The results are presented for 22 participants.</p> <p>Author written to for further details.</p>	

Risk of bias

Inspiratory muscle training for asthma (Review)

Weiner 2000 (Continued)

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote (from report): "were randomised into two groups" Comment: insufficient information provided
Allocation concealment (selection bias)	Unclear risk	Information not available
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Quote (from report): "as were the participants themselves, who were also blinded to the mode of treatment" Comment: blinding of participants was ensured
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote (from report): "all the data were collected by the same person, who was blinded to the training group designation" Comment: blinding of outcome assessment was ensured
Incomplete outcome data (attrition bias) All outcomes	Low risk	Only one patient was dropped from the study group because of the exacerbation in his asthma
Selective reporting (reporting bias)	Unclear risk	Data not available for lung function and the standard deviation for dyspnoea not presented
Other bias	Unclear risk	Insufficient information to assess whether an important risk of bias exists

Weiner 2002

Methods	A double-blind (assessors and participants) randomised controlled trial which took place in Israel. The trial had a two week run in period and an intervention phase that was terminated when the inspiratory muscle strength of each individual subject increased by greater than 20 cmH ₂ O over the baseline value in the study group (within 16 to 25 weeks) and after 12 weeks in the control group.
Participants	<p>Participants satisfied the American Thoracic Society definition of asthma, with symptoms of episodic wheezing, cough, and shortness of breath responding to bronchodilators and reversible airflow obstruction documented in at least one previous pulmonary function study.</p> <p>All participants had mild-to-moderate asthma (defined by FEV₁ greater than 60% of predicted normal values) and were treated by their primary physicians with inhaled corticosteroids and beta₂-agonists as required.</p> <p>Exclusion criteria were not described</p> <p>Thirty consecutive participants (17 male and 13 female participants) were recruited for the study and were randomised into two groups:</p> <p>Group A (intervention): mean $\pm$ SEM N = 15 M/F = 9/6 Mean Age = 39.7 $\pm$ 5.0 yrs</p> <p>Group B (Control) N = 15 M/F = 8/7 Mean Age = 37.1 $\pm$ 4.8 yrs</p>
Interventions	<p>Subjects in both groups trained once per day, six days per week; each session consisting of 30 minutes of training.</p> <p>The intervention group trained with resistance equal to 15% of their P_Imax for one week increasing by 5-10% each session through the first month to 60% of their P_Imax. The training was continued at 60% of P_Imax with the load level adjusted every week according to the new P_Imax achieved.</p>

Weiner 2002 (Continued)

Control group participants trained through the same training device with no resistance.

Outcomes	PI _{max} , beta ₂ -agonist consumption, dyspnoea using modified Borg scale, FEV ₁ , FVC, PEFR
Notes	Two participants dropped out of the study group, one due to an exacerbation, and one to a lack of compliance. Four participants dropped out of the control group after becoming aware of the sham training. The authors do not state how these four participants became aware of sham IMT (which questions blinding techniques used). Author written to for further details.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote (from report): "subjects were randomised" Comment: insufficient information provided
Allocation concealment (selection bias)	Unclear risk	Information not available
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Quote (from report): "as were the patients themselves, who were also blinded to the mode of treatment" Quote (from report): "four patients dropped out of the control group after becoming aware of the sham training" Comment: blinding of participants was broken, but the patients who become aware was excluded of the study
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote (from report): "all the data were collected by the same individual, who were blinded to the training group" Comment: blinding of outcome assessors was ensured
Incomplete outcome data (attrition bias) All outcomes	High risk	Quote (from report): "two participants dropped out of the study group, one due to an exacerbation, and one to a lack of compliance, four patients dropped out of the control group after becoming aware of the sham training" Comment: There was an imbalance in the control group (26%) versus the intervention group (13%) and the reasons for missing outcomes differed.
Selective reporting (reporting bias)	Unclear risk	Numerical outcome data for lung function, dyspnoea and beta ₂ -agonist consumption not presented, therefore, cannot be meta-analysed
Other bias	High risk	The length of the interventions, and therefore the time points for outcome assessment, were variable

Weiner 2002a

Methods	A double-blind (assessors and participants) randomised controlled trial which took place in Israel. The trial had a two week run in period and an intervention phase that was terminated when the mean inspiratory muscle strength of the group met that of the male with asthma (20 weeks).
Participants	Participants satisfied the American Thoracic Society definition of asthma, with symptoms of episodic wheezing, cough, and shortness of breath responding to bronchodilators and reversible airflow obstruction documented in at least one previous pulmonary function study. Participants had mild-to-moderate asthma (defined by FEV ₁ > 60% of predicted normal values).

Weiner 2002a (Continued)

All participants were treated by their primary physician only with inhaled corticosteroids and beta₂-agonists, as required. The anti-inflammatory treatment was kept stable during the whole period of the study.

Exclusion criteria are not described

Forty-four participants (22 male and 22 female) were recruited for the study. Men were found to have higher mean inspiratory muscle strength, therefore in the second stage of the study the female subjects (mean age in years $\pm$ SEM = 36.2 $\pm$ 3.1) were randomised into two groups:

Intervention

N = 11

Control

N = 11

Interventions	Subjects in both groups trained daily, six times a week, each session consisting of 30 minutes of training. Intervention group trained with resistance equal to 15% of their PImax for one week increasing by 5-10% each session through the first month to 60% of their PImax. The training was continued at 60% of PImax with the load level adjusted every week according to the new PImax achieved. Control group participants trained through the same training device with no resistance
Outcomes	FVC, FEV1, PImax, dyspnoea using modified Borg scale, beta ₂ -agonist consumption
Notes	One participant dropped out of the training group. Two participants dropped out of the control group after becoming aware of the sham training. Therefore the results are reported for the remaining 19 participants. Author written to for further details.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Comment: Insufficient information provided.
Allocation concealment (selection bias)	Unclear risk	Information not available.
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Quote (from report): "patients were also blinded to the mode of treatment"; Quote (from report): "one patient from the study group and two women from the control group who became aware that they had received sham training dropped out of the study". Comment: Blinding of participants was broken, but the patients who become aware was excluded of the study.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote (from report): "all data were collected by the same person, who was blinded to the mode of training" Comment: blinding of outcome assessment was ensured
Incomplete outcome data (attrition bias) All outcomes	Low risk	Quote (from report): "one patient from the study group and two women from the control group who became aware that they had received sham training dropped out of the study, so we report here the results of the remaining 19 patients". Comment: There was a balance in numbers of dropouts and similar reasons for missing data across groups.
Selective reporting (reporting bias)	Unclear risk	Numerical outcome data for PImax, lung function, Borg score and beta ₂ -agonist consumption not presented, therefore, cannot be meta-analysed

Weiner 2002a (Continued)

Other bias	High risk	The length of the interventions, and therefore the time points for outcome assessment, were variable.
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SD: standard deviation

SEM: standard error of a mean

PI_{max}: maximal inspiratory pressure

FEV₁: forced expiratory volume in one second

FVC: forced vital capacity

PE_{max}: maximum expiratory pressure

PEFR: peak expiratory flow rate

Characteristics of excluded studies [ordered by study ID]

Study	Reason for exclusion
Flynn 1989	Study included participants with COPD and not asthma
Guyatt 1992	Study included participants with COPD and not asthma
Jones 1985	Study included participants with COPD and not asthma
Lima 2008	Inadequate intervention group - inspiratory muscle training and breathing exercises
Lisboa 1994	Study included participants with COPD and not asthma
Lisboa 1997	Study included participants with COPD and not asthma.
McKeon 1986	Study included participants with COPD and not asthma
Pardy 1981	Study included participants with COPD and not asthma
Shaw 2011	No use of an external inspiratory muscle training device
Shaw 2011a	No use of an external inspiratory muscle training device
Turner 2011	Not a randomised trial
Weiner 1992	Not a randomised trial

COPD: chronic obstructive pulmonary disease

DATA AND ANALYSES

Comparison 1. Inspiratory muscle training versus control

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 PI _{max} - cmH ₂ O	4	84	Mean Difference (IV, Fixed, 95% CI)	13.34 [4.70, 21.98]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2 PEmax - cmH ₂ O	2	38	Mean Difference (IV, Fixed, 95% CI)	14.46 [-2.93, 31.84]
3 FEV1 L (actual values at end of intervention)	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4 FVC L (actual values at end of intervention)	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
5 PEFR L/min (actual values at end of intervention)	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
6 Dyspnoea	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
7 Use of beta2-agonists - puffs per day	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

Analysis 1.1. Comparison 1 Inspiratory muscle training versus control, Outcome 1 PImax - cmH₂O.

Analysis 1.2. Comparison 1 Inspiratory muscle training versus control, Outcome 2 PEmax - cmH₂O.

Analysis 1.3. Comparison 1 Inspiratory muscle training versus control, Outcome 3 FEV1 L (actual values at end of intervention).

Study or subgroup	IMT Group		Control Group		Mean Difference	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Fixed, 95% CI	Fixed, 95% CI
McConnell 1998	9	3.8 (0.6)	9	3.6 (1)		0.2[-0.54,0.94]
					Favours Control	Favours IMT

Analysis 1.4. Comparison 1 Inspiratory muscle training versus control, Outcome 4 FVC L (actual values at end of intervention).

Study or subgroup	IMT Group		Control Group		Mean Difference	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Fixed, 95% CI	Fixed, 95% CI
McConnell 1998	9	5.1 (0.9)	9	4.6 (1)		0.54[-0.32,1.4]
					Favours Control	Favours IMT

Analysis 1.5. Comparison 1 Inspiratory muscle training versus control, Outcome 5 PEFR L/min (actual values at end of intervention).

Study or subgroup	IMT Group		Control Group		Mean Difference	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Fixed, 95% CI	Fixed, 95% CI
McConnell 1998	9	551 (87)	9	523 (138)		28[-78.58,134.58]
					Favours Control	Favours IMT

Analysis 1.6. Comparison 1 Inspiratory muscle training versus control, Outcome 6 Dyspnoea.

Study or subgroup	IMT Group		Control Group		Mean Difference	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Fixed, 95% CI	Fixed, 95% CI
McConnell 1998	9	2.1 (0.9)	9	1.9 (0.7)		0.23[-0.53,0.99]
					Favours Control	Favours IMT

Analysis 1.7. Comparison 1 Inspiratory muscle training versus control, Outcome 7 Use of beta2-agonists - puffs per day.

Study or subgroup	IMT Group		Control Group		Mean Difference	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Fixed, 95% CI	Fixed, 95% CI
Weiner 2000	11	1.6 (4.4)	11	2.9 (4.4)		-1.3[-4.99,2.39]
					Favours IMT	Favours Control

APPENDICES

Appendix 1. Sources and search methods for the Cochrane Airways Group Specialised Register (CAGR)

Electronic searches: core databases

Database	Frequency of search
CENTRAL (<i>the Cochrane Library</i>)	Monthly
MEDLINE (Ovid)	Weekly
EMBASE (Ovid)	Weekly
PsycINFO (Ovid)	Monthly
CINAHL (EBSCO)	Monthly
AMED (EBSCO)	Monthly

Handsearches: core respiratory conference abstracts

Conference	Years searched
American Academy of Allergy, Asthma and Immunology (AAAAI)	2001 onwards
American Thoracic Society (ATS)	2001 onwards
Asia Pacific Society of Respiriology (APSR)	2004 onwards
British Thoracic Society Winter Meeting (BTS)	2000 onwards
Chest Meeting	2003 onwards
European Respiratory Society (ERS)	1992, 1994, 2000 onwards
International Primary Care Respiratory Group Congress (IPCRG)	2002 onwards
Thoracic Society of Australia and New Zealand (TSANZ)	1999 onwards

MEDLINE search strategy used to identify trials for the CAGR

Asthma search

1. exp Asthma/
2. asthma\$.mp.
3. (antiasthma\$ or anti-asthma\$).mp.

4. Respiratory Sounds/
5. wheez\$.mp.
6. Bronchial Spasm/
7. bronchospas\$.mp.
8. (bronch\$ adj3 spasm\$).mp.
9. bronchoconstrict\$.mp.
10. exp Bronchoconstriction/
11. (bronch\$ adj3 constrict\$).mp.
12. Bronchial Hyperreactivity/
13. Respiratory Hypersensitivity/
14. ((bronchial\$ or respiratory or airway\$ or lung\$) adj3 (hypersensitiv\$ or hyperreactiv\$ or allerg\$ or insufficiency)).mp.
15. ((dust or mite\$) adj3 (allerg\$ or hypersensitiv\$)).mp.
16. or/1-15

Filter to identify RCTs

1. exp "clinical trial [publication type]"/
2. (randomised or randomised).ab,ti.
3. placebo.ab,ti.
4. dt.fs.
5. randomly.ab,ti.
6. trial.ab,ti.
7. groups.ab,ti.
8. or/1-7
9. Animals/
10. Humans/
11. 9 not (9 and 10)
12. 8 not 11

The MEDLINE strategy and RCT filter are adapted to identify trials in other electronic databases.

Appendix 2. Database search strategies

Cochrane Airways Group Specialised Register

((inspiratory or ventilat* or respiratory) and muscle and (strength* or train* or endur*)) or IMT or RMT or (resistance* and train*) or "resistive breathing" or "threshold load*" or "threshold device"

[Limited to records coded as 'asthma']

CENTRAL in The Cochrane Library

- #1 MeSH descriptor Asthma explode all trees
- #2 asthma* or wheez*
- #3 (#1 OR #2)

Inspiratory muscle training for asthma (Review)

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- #4 MeSH descriptor Breathing Exercises, this term only
- #5 ((inspiratory or ventilat* or respiratory) and muscle and (strength* or train* or endur*))
- #6 IMT or RMT
- #7 resist* NEAR/3 train*
- #8 "resistive breathing"
- #9 "threshold load*"
- #10 "threshold device*"
- #11 (#4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10)
- #12 (#3 AND #11)

Clinicaltrials.gov

asthma and inspiratory muscle training
asthma and respiratory muscle training
asthma and IMT
asthma and RMT

WHAT'S NEW

Date	Event	Description
9 September 2013	Amended	Typo corrected in abstract.

HISTORY

Protocol first published: Issue 2, 2002
Review first published: Issue 4, 2003

Date	Event	Description
23 November 2012	New search has been performed	New literature search run.
23 November 2012	New citation required and conclusions have changed	Added new included study (Sampaio 2002) and excluded a trial that was included in a previous version of the review (Weiner 1992). Amendments made to Plain Language Summary and Background, reformatted Results, Discussion and Conclusions and added 'Risk of bias' table. New review team.
31 July 2008	Amended	Converted to new review format.
8 April 2003	New citation required and conclusions have changed	Substantive amendment

CONTRIBUTIONS OF AUTHORS

ISS: screening search results, eligibility and assessment of risk of bias, data extraction, data entry, analysis, interpretation and drafting review.

GAFF: data extraction and drafting review.

Inspiratory muscle training for asthma (Review)

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FALD: Interpretation and drafting review.

CTDR: screening search results, eligibility and assessment of risk of bias.

ROG: analysis and interpretation.

GMHF: co-ordinating review team, eligibility and assessment of risk of bias, interpretation and drafting review.

DECLARATIONS OF INTEREST

There are no known conflicts of interest.

SOURCES OF SUPPORT

Internal sources

- None, Not specified.

External sources

- None, Not specified.

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

A new author team conducted the 2013 update.

INDEX TERMS

Medical Subject Headings (MeSH)

Asthma [*rehabilitation]; Breathing Exercises [*methods]; Muscle Strength [physiology]; Randomized Controlled Trials as Topic; Respiratory Muscles [*physiopathology]; Respiratory Therapy [instrumentation] [*methods]

MeSH check words

Adult; Humans