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REVIEW

The effectiveness of physiotherapy in patients with asthma: A systematic review of the literature

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Summary
Since the introduction of medical therapy for asthma the interest in non-medical treatments deteriorated. Physiotherapy could have beneficial effects in asthmatics. This review investigates the effectiveness of physiotherapy in the treatment of patients with asthma.

A review was performed on the terms breathing exercises (BE), inspiratory muscle training (IMT), physical training (PhT) and airway clearance (AC) in patients with asthma.

The search resulted in 237 potentially relevant articles, after exclusion 23 articles remained. BE ($n = 9$) may improve disease specific quality of life (QoL), reduce symptoms, hyperventilation, anxiety and depression, lower respiratory rate and medication use. IMT ($n = 3$) can improve inspiratory pressure and may reduce medication use and symptoms. PhT ($n = 12$) can reduce symptoms, improve QoL and improve cardiopulmonary endurance and fitness.

In conclusion, physiotherapy may improve QoL, cardiopulmonary fitness and inspiratory pressure and reduce symptoms and medication use. Further studies, investigating combinations of techniques, are needed to confirm these findings.

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Introduction

Asthma is an inflammatory disorder with airway hyperresponsiveness leading to recurrent episodes of wheezing, breathlessness, chest tightness and coughing, especially during the night and the early morning.[1,2] Asthma develops primarily at a young age, but may also occur in adulthood. The prevalence of asthma is about 5—10% in children[1] and approximately 3% in adults.[3]

Asthma has a significant impact on individuals in terms of quality of life, it affects school or work attendance and performance and reduces activity levels. The treatment of asthma consists of both medical, primarily through inhalation medication, and non-medical therapy. The aim of treatment is to achieve a normal lifestyle with a normal exercise capacity, the avoidance of serious asthma attacks and the achievement of an optimal lung function with as few symptoms as possible.[1,3] Since the introduction of medical therapy for asthma, interest in non-medical treatments deteriorated.

Non-medical treatment of asthma may consist of several aspects including education, guidance of patients and various forms of physiotherapy. Physiotherapy may have beneficial effects since most asthmatics have a dysfunctional breathing pattern and poor physical condition. As a consequence, this may cause problems in participation in sports, school gymnastics and playing outside.

Cochrane reviews concerning physiotherapy

In the last decade five Cochrane reviews[4—8] were published concerning physiotherapy in children and adults with asthma. These reviews examined the effect of various treatments (namely Alexander technique,[4] breathing exercises,[5] manual therapy,[6] physical training,[7] and inspiratory muscle training (IMT)[8]) in patients with asthma. For two reviews, the number of included studies were too small to draw conclusions.[4,6] The other three reviews[5,7,8] did find several significant results, but due to the small number of included studies, the small patient numbers per study and the different methods and outcome measures, the reliability of these results is limited. From these five Cochrane reviews it can be concluded that too little reliable studies have been performed to draw a conclusion on the effectiveness of physiotherapy in asthma. Furthermore, literature searches for these reviews took place up to 2002 (IMT), 2003 (breathing exercise), 2004 (manual therapy) 2005 (physical training) and 2010 (Alexander), which underlines the need for an update of the literature.

Despite the limitations of the Cochrane reviews, especially the three physiotherapy techniques breathing exercises, IMT and physical training are techniques which are promising in asthmatics and which are practiced by various patients.

Breathing exercises and asthma

The most frequently mentioned aims of breathing exercises are to 'normalize' breathing pattern by adopting a slower respiratory rate with longer expiration and reduction of hyperventilation and hyperinflation. Training also frequently involves encouraging nasal breathing and a diaphragmatic breathing pattern.[9] This is based on the assumption that patients with asthma have abnormal or dysfunctional breathing patterns.[9]

Inspiratory muscle training and asthma

Inspiratory muscles can be trained for both strength and endurance with an external resistive device.[8] Exercise-induced bronchoconstriction (EIB) as well as chronic bronchoconstriction in asthmatics is associated with increased inspiratory muscle work. It is reasonable to suggest that increasing the strength of the inspiratory muscles in people with asthma may reduce the intensity of dyspnea and improves exercise tolerance.[10] It is possible that a loss of muscle mass, including the respiratory muscles, occurs in asthmatics, related to the effects of treatment with corticosteroids.[8] So, it may be a suitable target for training.[8]

Physical training and asthma

Although aerobic exercise can provoke EIB in patients with asthma,[11] regular physical activity and participation in sports are considered to be important components in the overall management of asthma.[7] Nevertheless, the fear of inducing an episode of breathlessness inhibits many asthmatics from taking part in physical activities. A low level of physical activity in turn leads to a low level of physical fitness. Physical training programmes have been designed for asthmatics with the aim of improving physical fitness, neuromuscular coordination and self-confidence.[7]

Guidelines concerning physiotherapy and asthma

A recent international guideline[12] regarding physiotherapeutic management of adult patients recommends breathing exercises for patients with asthma to increase asthma control and quality of life (evidence grade A). Physical training is advised to increase fitness and cardiorespiratory endurance, to decrease dyspnea and improve quality of life (evidence grade B). The Dutch general practitioner guideline to treat children with asthma does not mention the treatment possibilities concerning physiotherapy.[1] The most important reason not to mention this possibility is lack of evidence. However, the Dutch GP guideline to treat adults with asthma advises patients with asthma to exercise for approximately 30 min a day to increase fitness and cardio-respiratory endurance. If this is not successful, the general practitioner can consider to refer the patient to a physiotherapist.[3] The Royal Dutch Society of Physiotherapy (KNGF) has formulated the guideline 'Asthma in children'.[13] This consensus-based guideline describes the diagnostic and therapeutic process in children with asthma. The treatment goals are promoting compliance to medication, improving exercise tolerance, respiratory conditions and airway clearance.

In conclusion, there is much uncertainty about the role of physiotherapy in patients with asthma. Because the Cochrane reviews on this subject are published already about 7–10 years ago, the aims of this review are summarizing results of recent literature and evaluating if additional conclusions are possible in comparison to the former Cochrane reviews. In order to investigate this topic, literature concerning the most relevant treatment options i.e. breathing exercises (BE), inspiratory muscle training (IMT), physical training (PhT) and airway clearance (AC) is searched after the publication of three Cochrane reviews concerning these treatments.

Methods

Types of studies

Randomized controlled trials regarding breathing exercises, inspiratory muscle training, physical exercises or airway clearance in patients diagnosed with asthma published after the last search date of the relevant Cochrane reviews.

Types of participants

Patients of any age diagnosed with asthma. Subjects with any degree of asthma severity could be included. Whereas patients of all ages could be included, we made a distinction between adult patients and children. When for a specific physiotherapy treatment, at least five studies about children could be found, we reported the results for children separately.

Types of interventions

We included all studies that examined the use of one or more types of physiotherapy, including breathing exercises, inspiratory muscle training, physical exercises or airway clearance techniques compared with a control group. The control group may consist of usual care, education, a waiting list group or other forms of exercises.

Outcome measures

Categories of outcomes examined for this review are based on outcome measures used in the Cochrane reviews.[4,8] These are based on subjective patient relevant outcomes for asthma (quality of life, symptoms, asthma control), objective patient relevant outcomes for asthma (exacerbations/asthma attacks, medication use, hospitalizations and visits to a doctor), outcomes indirectly related to asthma (anxiety and depression, Nijmegen hyperventilation questionnaire, Borg scale) and lung function measurement. As outcome measurements for lung function we used forced expiratory volume in the first second (FEV_1), forced vital capacity (FVC), peak expiratory flow rate (PEFR), maximal inspiratory pressure (PI_{max} or MIP), maximum oxygen uptake (VO_{2max}), end tidal carbon dioxide concentration ($ETCO_2$), minute volume (MV) and respiratory rate (RR).

Search methods for identification of studies

Literature search was conducted in the Cochrane Library and PubMed. First, we searched for reviews in the Cochrane Library to investigate what is already known about physiotherapy in patients with asthma. In our search for new studies, we searched in Pubmed identifying randomized controlled trials published after the most recent search of the Cochrane review up to March 5, 2012. Because there is no Cochrane review on airway clearance in asthma, this search strategy has no limit on data. Articles on airway clearance were searched electronically from inception to March 5, 2012. Table 1 shows the various search strategies and limits that we used in PubMed for the various physiotherapy treatments.

Study selection and data extraction

As the first phase of screening, two reviewers (M.B. and H.M.) independently examined the titles and abstracts of the search results, the second phase of screening was based on full-text articles. Titles, abstracts and full-text articles were assessed for inclusion with the previously mentioned inclusion criteria. Disagreement between reviewers on inclusion was resolved trough discussion. There were no articles for which consensus could not be achieved.

Results

The search of the PubMed database for breathing exercises resulted in 34 references, for inspiratory muscle training in 42 references, for physical training in 161 references and for airway clearance in 0 references. Added together, it gives a total of 237 potentially relevant articles (Fig. 1). After reading the titles and abstracts, 213 articles were excluded not meeting the inclusion criteria. The full text of the remaining 24 articles was examined in more detail. These were nine articles on breathing exercises, three articles on IMT and 12 articles on physical training. Only one study did not meet the inclusion criteria (not a randomized controlled trial). Two articles[14,15] were found in two of the search strategies, so a total of 21 articles remained. One study[15] addressed both IMT and physical exercises, and one study[14] addressed both breathing exercises and IMT, these studies will be reported under both headings.

Breathing exercises

Table 2 illustrates the results from the Cochrane review on breathing exercises for asthma and the nine included studies after the Cochrane review. Different breathing exercises were used in these studies, but most trials used one or more of the following components: nasal route of breathing, diaphragmatic breathing pattern, breath holdings or hypoventilation.

Of these nine studies, the most frequently studied outcome is disease specific quality of life: five trials[16–20] determined this outcome. Three of these studies[17,18,20] found a significant improvement compared to the control group. The two studies[16,19] without significant improvement used control groups including other forms of breathing exercises. This resulted in a significant improvement in quality of life in both groups.[16]

Another commonly used outcome measure is asthma symptoms: five trials[14,18,19,21,22] examined this outcome. Three of the five studies[14,18,19] found a significant improvement compared to the control group. Asthma control was examined in five studies.[16,17,19,20,22] Only two studies[17,22] found significant improvement. One of them[22] found significant improvement within the training group, in the other study[17] the significant difference between the groups disappeared after 3 months.

All nine trials described one or more lung function measurements. FEV_1 was measured in six studies,[16,17,19,20,22,23] FVC in three studies,[19,22,23] and PEF(R) in four studies.[14,21–23] Remarkably, almost no significant differences were found in lung function measurements. One study[14] described a significant improvement of PEF and another study[23] of FEV_1. No studies found a significant improvement in FVC.

Studies on breathing exercises often include measures of carbon dioxide levels ($ETCO_2$), five studies included this outcome measure.[17–20,22] It is thought that hypocapnia is a major contributor to the symptoms of asthma and therefore exercises to reduce minute volume (e.g. the Buteyko technique) could reduce symptoms.[5] Only one study[17] found significant increase of $ETCO_2$ compared to the control group. Another study[22] also found a significant increase in $ETCO_2$, but this was only within the training group.

All studies which examined anxiety and/or depression[18,20,21] found a significant difference between the groups, in favor of breathing exercises. Same is true for

Table 1 Search strategies PubMed.

Topic	Search strategy	Limits
Airway clearance	Asthma [Mesh] AND physiotherap* AND (airway clearance *" OR airway clearance technique*" OR sputum clearance *")	Randomized Controlled Trial, English, Dutch
Breathing exercises	Asthma [Mesh] AND (breath*) AND (exercise* OR retrain* OR train* OR re-educat* OR educate* OR physiotherap* OR "physical therap*" OR "respiratory therapy" OR buteyko)	Randomized Controlled Trial, English, Dutch, Publication Date from 2003 to 2012
Inspiratory muscle training	Asthma [Mesh] AND (IMT OR "inspiratory muscle train*" OR "respiratory muscle training" OR "respiratory muscle strength" OR "respiratory muscle endurance")	Randomized Controlled Trial, English, Dutch, Publication Date from 2003 to 2012
Physical training	Asthma [Mesh] AND ("work capacity" OR (physical* AND activity*) OR train* OR rehabilitat* OR fitness* OR exercis*)	Randomized Controlled Trial, English, Dutch, Publication Date from 2005 to 2012

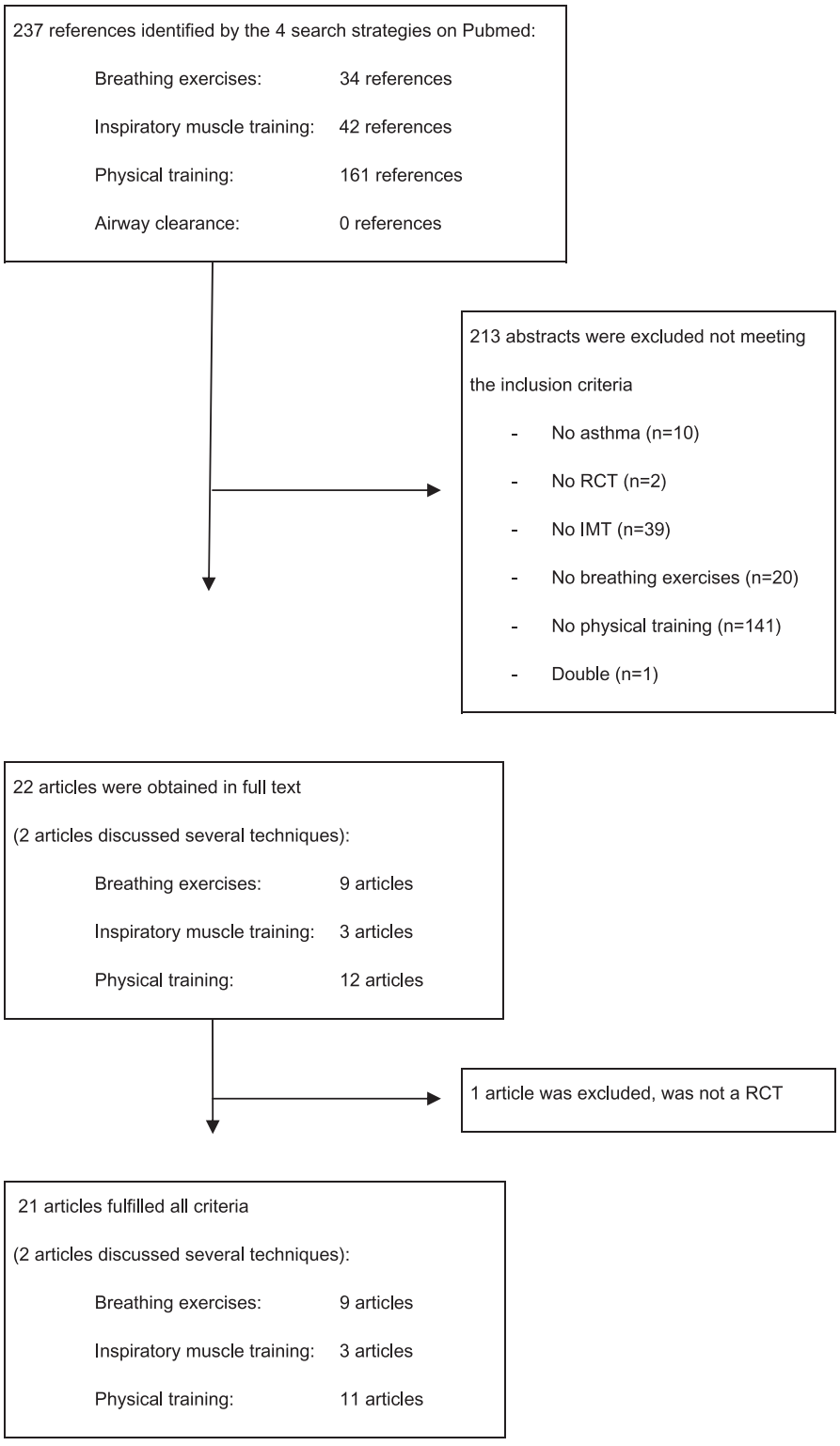

Figure 1 Flow chart of the literature search and selection.

respiratory rate, all three studies[17,18,22] that examined this outcome found a significant decrease, one study[22] only within the training group. In three studies,[17,18,20] the patients were asked to complete the Nijmegen hyperventilation questionnaire (NQ). Two studies[18,20] found a significant decrease in the NQ score.

Four trials[14,16,19,21] have investigated whether medication use (bronchodilators or corticosteroids) is reduced through breathing exercises, two[14,16] found a significant decrease.

In conclusion, breathing exercises may improve disease specific quality of life, reduce symptoms, hyperventilation,

Table 2 Cochrane review and randomized controlled trials on breathing exercises for asthma.

First author (date)	Study participants	Study design	Measurement points	Outcome measures	Significant results between groups
Holloway (2004)[5]	359 patients (7 studies)	Cochrane review	Range training and follow up: 3 weeks—30 months	QoL, symptoms, exacerbations, hospitalizations, PEFR, FEV_1, FVC, MV, medication use, visits to GP/hospital	↑ QoL (2/2)[a] ↓ Bronchodilator use (2/3)[a] ↓Exacerbations (1/3)[a] ↓ ICS use (1/3)[a] ↓ MV (1/1) ↑ PEFR (1/3)[a]
Slader (2006)[19]	57 patients 15—80 years 2 groups	1. Shallow nasal breathing 2. Non-specific upper body exercises	Baseline 12 weeks 28 weeks[e]	AQLQ, ACQ, FEV_1%, FVC%, $ETCO_2$, symptoms, use of reliever	↓ Symptoms (group 2)
Holloway (2007)[18]	85 patients >18 years 2 groups	1. Papworth method 2. Control	Baseline 6 months[e] 12 months	Symptoms, QoL, HADS, RR, NQ, $ETCO_2$	↓ Symptoms ↑ QoL ↓ HADS[b] ↓ NQ[b] ↓ RR
Meuret (2007)[22]	12 patients 18—60 years 2 groups	1. Capnometer-assisted breathing exercises 2. Waiting list group	Baseline 4 weeks[e] 8 weeks	$ETCO_2$, FEV_1, FVC, PEF, RR, symptoms, ACQ	No significant results between groups (↑ $ETCO_2$[d]) (↓ RR[d]) (↓ Symptoms[d]) (↓ ACQ[b,d])
Cowie (2008)[16]	129 patients 18—50 years 2 groups	1. BBT 2. Breathing exercises	Baseline 1 month (spirometry) 3 months 6 months[e]	ACQ, medication use, QoL, FEV_1	↓ B_2-agonist use ↓ ICS use
Lima (2008)[14]	50 patients 8—12 years 2 groups	1. Education + IMT + breathing exercises 2. Education	Baseline 7 weeks[e] 3 months	PEF, MIP, asthma-attacks, daily/nocturnal symptoms, ER visits, hospitalizations, bronchodilator-use	↑ PEF ↑ MIP ↓ Asthma attacks ↓ Nocturnal symptoms ↓ Bronchodilator-use ↑ ADL
Chiang (2009)[21]	48 patients 6—14 years 2 groups	1. Self-management program + relaxation-breathing training 2. Self-management program	Baseline 12 weeks[e]	Anxiety (CCAS), health status, symptoms, PEFR, medication	↓Anxiety[b]
Thomas (2009)[20]	183 patients >18 years 2 groups	1. Papworth + education 2. Education	Baseline 1 month 6 months[e]	AQLQ, ACQ, HADS, NQ, FEV_1, $ETCO_2$, MV	↑ AQLQ ↓ HADS[b] ↓ NQ[b]

Sodhi (2009)[23]	120 patients 17–50 years 2 groups	1. Yoga breathing exercises 2. Control	Baseline 4 weeks 8 weeks[e]	PEFR, FEV_1, FVC	↑ FEV_1
Grammatopoulou (2011)[17]	40 patients >18 years 2 groups	1. Breathing exercises + education + action plan 2. Control	Baseline 1 month 3 months 6 months[e]	ACT, NQ, QOLQ, $ETCO_2$, RR, FEV_1, MRC	↑ ACT[c] (until month 3) ↑ $ETCO_2$ ↓ RR ↑ Physical QOLQ (until month 3)

QoL = Quality of life; PEF(R) = peak expiratory flow (rate); FEV_1(%) = forced expiratory volume in one second (of predicted); FVC(%) = forced vital capacity (of predicted); MV = minute volume; ICS = inhaled corticosteroids; AQLQ = Asthma quality of life questionnaire; ACQ/ACT = Asthma control questionnaire/test; $ETCO_2$ = end tidal carbon dioxide concentration; HADS = Hospital anxiety and depression score; RR = respiratory rate; NQ = Nijmegen hyperventilation questionnaire; BBT = Buteyko Breathing Technique; IMT = inspiratory muscle training; MIP = maximal inspiratory pressure; CCAS = Chinese Children's Anxiety Scale; MRC = Medical Research Council (MRC) breathlessness scale.

[a] No pooled significant results possible.
[b] Lower is better.
[c] Higher is better.
[d] Significant pre versus post training **within** trainings group.
[e] End training.

anxiety and depression, lower respiratory rate and medication use, but it does not affect lung function.

Inspiratory muscle training

The number of RCTs that studied the effect of inspiratory muscle training (IMT) in patients with asthma is scarce. Table 3 illustrates the Cochrane review and three included studies since the Cochrane review. Two of the three trials mainly examined changes in lung function. Subjective outcome measures such as quality of life and asthma control are not examined in these studies.

Two of the three trials[10,14] examined whether the maximal inspiratory pressure (PI_{max}) changed through IMT. Both studies found a significant increase in PI_{max} after training, compared to the control group[14] or pre versus post training.[10]

Only one study[14] examined whether IMT can reduce symptoms, this study found a significant decrease in nocturnal symptoms compared to the control group. Beside the improvement of PI_{max}, not many significant improvements in lung function are found. One[14] of the two studies which examined PEF found a significant increase. Also only one study[14] has examined medication use, this study found a significant reduction in bronchodilator use.

In conclusion, inspiratory muscle training can improve maximal inspiratory pressure and might reduce medication use, reduce symptoms and improve lung function, but the number of studies is limited.

Physical training

Table 4 illustrates the Cochrane review and the 11 included studies on physical exercises for asthma since the review. Six studies examined whether physical training improves disease specific quality of life and five out of six found significant improvements. One study[24] reported significant higher quality of life scores within the exercise group after training, but the scores were not significant between the groups. Three studies[11,25,26] looked at the effect of physical training on asthma symptoms. One study[26] found significant reduction of symptoms, another study[11] found an increase in the number of symptom free days. Asthma control was examined by one study[27] only, without a significant improvement. Three studies[25,28,29] examined whether physical training can reduce medication use, only one study[29] found a significant decrease of inhaled corticosteroids.

Almost all studies have determined pulmonary function tests. Three studies[11,26,28] measured the maximum oxygen uptake capacity (VO_{2max}). VO_{2max} determines how much oxygen a person can utilize in one minute during maximum exertion. It is generally considered the best indicator of cardiorespiratory endurance and aerobic fitness. All three studies found a significant increase after training compared to the control group. Besides VO_{2max}, many studies have examined FEV_1 (9 studies), FVC (7 studies) and PEF (4 studies). Only one[15] of the studies that have examined FEV_1 and FVC found significant improvements compared to the controls. Also PEF improved only in one study.[30]

Seven of the 11 included studies are specifically about children with asthma. From these seven studies it can be concluded that physical training in children with asthma

Table 3 Cochrane review and randomized controlled trials on inspiratory muscle training (IMT) for asthma.

First author (date)	Study participants	Study design	Measurement points	Outcome measures	Significant results between groups
Ram (2003)[8]	186 patients (5 studies)	Cochrane review	Range training: 3 weeks–6 months	PI_{max}, FEV_1, FVC, PEFR, PE_{max}, symptoms, visits to hospital/ER, bronchodilator use, ICS use, exacerbations, days off work/school	↑ PI_{max} (2/4) ↑ FVC (1/2) ↓ Bronchodilator use (1/1)
Lima (2008)[14]	50 patients 8–12 years 2 groups	1. Education + IMT + breathing exercises 2. Education	Baseline 7 weeks[c] 3 months	PEF, MIP, asthma-attacks, daily/nocturnal symptoms, ER visits, hospitalizations, bronchodilator-use	↑ PEF, MIP ↓ Asthma attacks ↓ Nocturnal symptoms ↓ Bronchodilator-use
Turner (2011)[10]	15 patients >18 years 2 groups	1. IMT training 2. Placebo	Baseline 6 weeks[c]	FVC, FEV_1, PI_{max},, RR, Borg score (dyspnea), VO_2	No significant results between groups (↑ PI_{max}[b]) (↓ VO_2[b]) (↓ Borgscore[a,b])
Shaw (2011)[15]	88 patients 18–34 years 4 groups	1. Aerobic exercise (AE) 2. Diaphragmatic inspiratory resistive breathing (DR) 3. AE + DR (CE) 4. Control (NE)	Baseline 8 weeks[c]	FVC, FEV_1, PEF, V_E, RR, MVV	↑ FVC, FEV_1 (CE versus AE)

PI_{max}/MIP = maximal inspiratory pressure; FEV_1 = forced expiratory volume in one second; FVC = Forced vital capacity; PEF(R) = peak expiratory flow (rate); PE_{max} = maximal expiratory pressure; ER = emergency room; ICS = inhaled corticosteroids; IMT = inspiratory muscle training; RR = respiratory rate; VO_2 = peak oxygen consumption; V_E = minute ventilation; MVV = maximal voluntary ventilation.

[a] Lower is better.

[b] Significant pre versus post training **within** trainings group.

[c] End training.

can improve disease specific quality of life; three[25,28,29] of the four trials[24,25,28,29] which investigated this outcome did find significant improvement. Also, it can be concluded that physical training does not affect lung function in children with asthma. Other conclusions can not be drawn, because further benefits of physical training in children with asthma were found in isolated outcome measures in single studies.

Concluding, in patients with asthma physical exercise can improve disease specific quality of life, reduces symptoms and improves cardiopulmonary endurance and fitness without changing lung function.

Airway clearance

As mentioned in the Dutch physiotherapists' guideline,[13] physiotherapists also use techniques to improve airway clearance. We found no studies that describe the effect of sputum mobilization in patients with asthma. There are only studies on physiotherapeutic interventions to improve airway clearance in patients with cystic fibrosis (CF).

Discussion

The aim of the present study was to investigate, through a review of the literature, whether physiotherapy can play a role in the treatment of patients with asthma. Our review is, to our knowledge, the first review on various physiotherapeutic treatments. This review shows that physiotherapy can have beneficial effects in asthmatics. The main findings are that physiotherapy may improve disease specific quality of life, cardiopulmonary fitness and maximal inspiratory pressure and reduce symptoms and medication use.

Breathing exercises and asthma

As already was found in the Cochrane review on breathing exercises,[5] our review shows that trials published after the Cochrane review reported improvement in quality of life and reduction of medication use and respiratory rate. In addition, in our review we found that breathing exercises can reduce symptoms, hyperventilation, anxiety and

Table 4 Cochrane review and randomized controlled trials on physical exercises for asthma.

First author (date)	Study participants	Study design	Training	Measurement points	Outcome measures	Significant results between groups
Ram (2005)[7]	455 patients (13 studies)	Cochrane review	Range: 1.5—3 months	—	Bronchodilator usage, episodes of wheeze, symptoms, exercise endurance, work capacity, walking distance, QoL, PEFR, FEV_1, FVC, VO_{2max}, VE_{max}, HR_{max}, MVV	↑ VE_{max} (1/4) ↑ VO_{2max} (4/7) ↑ HR_{max} (3/5) ↑ Work capacity (2/3)
Basaran (2006)[25]	58 patients 7—15 years 2 groups	1. Basketball training 2. Control	8 weeks 3×/week 60 min/session	Baseline 8 weeks	PAQLQ, medication use, symptoms, FEV_1, FVC, PEF	↑ PAQLQ
Fanelli (2007)[28]	38 patients 7—15 years 2 groups	1. Education + training 2. Education	16 weeks 2×/week 90 min/session	Baseline 16 weeks	FVC, FEV_1, MVV, VO_2, Borg score (dyspnea), PAQLQ, ICS use	↑ PAQLQ ↓ Borg score[a] ↑ VO_2
Flapper (2008)[29]	36 patients 8—12 years 2 groups	1. Education-exercise group 2. Control	10 weeks 1×/week 90 min education + 60 min training/ session	Baseline 3 months 6 months 9 months (training)	FEV_1, asthma severity score, visits to GP/ER /hospital, asthma-attacks, days absent from school/work, HRQoL, ICS use	↓ Visits GP/ pediatrician ↓ ICS use ↓ Days absent from school ↑HROoL[b]
Moreira (2008)[24]	34 patients 9—16 years 2 groups	1. Exercise group 2. Control	12 weeks 2×/week 50 min/session	Baseline 12 weeks	PAQLQ, FEV_1, PEF	—
Wang (2009)[30]	30 patients 7—12 years 2 groups	1. Swimming training 2. Control	6 weeks 3×/week 50 min/session	Baseline 6 weeks Daily: PEF, severity	FVC, FEV_1, PEF, severity of asthma	↑ PEF ↓ Severity of asthma
Mendes (2010)[11]	101 patients 20—50 years 2 groups	1. Education + breathing exercises + training 2. Education + breathing exercises	3 months 2×/week 30 min/session	Baseline 1 month (symptoms) 2 months (symptoms) 3 months	HRQoL, BDI, STAI, symptoms, VO_{2max}	↓ HRQoL score[a] ↓ Symptoms ↑ VO_{2max} ↓ BDI score[a] ↓ STAI score[a]
Wicher (2010)[31]	61 patients 7—18 years 2 groups	1. Swimming training 2. Control	3 months 2×/week 60 min/session	Baseline 3 months	FVC, FEV_1	—
Turner (2011)[27]	35 patients >40 years 2 groups	1. Exercise training 2. Usual care	6 weeks 3×/week 80—90 min/session	Baseline 6 weeks 3 months	AQLQ, HADS, ACQ, health status	↑ AQLQ ↑ Physical component health status

(*continued on next page*)

Table 4 (*continued*)

First author (date)	Study participants	Study design	Training	Measurement points	Outcome measures	Significant results between groups
Mendes (2011)[26]	68 patients 20—50 years 2 groups	1. Education + breathing exercises + aerobic training 2. Education + breathing exercises	3 months 2×/week 30 min/session	Baseline 1 month (symptom free days) 2 months (symptom free days) 3 months	FEV_1, FVC, VO_{2max}, symptom free days	↑ VO_{2max} ↑ Symptom free days
Onur (2011)[32]	43 patients 8—13 years 3 groups	1a. Asthma + pharmacological treatment 1b. Asthma + pharmacological treatment + exercise programme 2. Healthy controls	8 weeks 2×/week 60 min/session	Baseline 8 weeks	FEV_1, FVC	No significant results between groups (↑ FEV_1 and FVC[c] (within 1b))
Shaw (2011)[15]	88 patients 18—34 years 4 groups	1. Aerobic exercise (AE) 2. Diaphragmatic inspiratory resistive breathing (DR) 3. AE + DR (CE) 4. Control (NE)	8 weeks 3×/week 40 min/session (AE)	Baseline 8 weeks	FVC, FEV_1, PEF, V_E, RR, MVV	↑ FVC, FEV_1 (CE versus AE)

QoL = quality of life; PEF(R) = peak expiratory flow (rate); FEV_1 = 1-s forced expiratory volume; FVC = forced vital capacity; $VO_{2(max)}$ = (maximal) oxygen uptake; VE_{max} = maximal ventilation during exercise; HR_{max} = maximal heart rate; MVV = maximal voluntary ventilation; (P)AQLQ = (Pediatric) Asthma Quality of Life Questionnaire; ICS = inhaled corticosteroids; HRQoL = health related quality of life; BDI = Beck depression inventory; STAI = State-trait anxiety inventory; HADS = Hospital anxiety and depression score; ACQ = Asthma Control Questionnaire; V_E = minute ventilation.

[a] lower is better.

[b] Higher is better.

[c] significant pre versus post training **within** trainings group.

depression. In a review published in 2011, Bruton et al.[9] examined the role of breathing training in asthma management. Five studies[16,18–21] are used in both their and our review. They also included articles published before the Cochrane review. Bruton et al.[9] conclude that breathing training may improve symptoms, quality of life and may reduce rescue bronchodilator use. This corresponds to our conclusion on breathing exercises.

Inspiratory muscle training and asthma

In the Cochrane review on IMT[8] it is concluded that IMT may improve PI_{max}, but there was insufficient evidence to suggest that it could provide any clinical benefits for patients with asthma. Besides the improvement of PI_{max}, we found reduction of symptoms and medication use, however this was investigated only in one of the three studies.

Physical training and asthma

Both the Cochrane review on physical training[7] and our review shows improvement on cardiopulmonary endurance and fitness (VO_{2max}). Although the Cochrane review[7] did not demonstrate this, our review found significant improvements in quality of life and symptoms after following physical training.

Interestingly, the emphasis on specific outcome measures has changed over the years. In the Cochrane reviews lung function was a very important outcome measure, often there were no data available from the various studies on symptoms, quality of life or asthma exacerbations. In recent studies it is exactly the opposite. Subjective outcome measures have become increasingly important, as this is the most important for the patient.

This review shows that the effect of physiotherapy in children suffering from asthma is poorly studied, whereas this is the group of patients in which asthma complaints most often start, in which participation in sport and school is of great importance and where, as a consequence, a large profit can be obtained. In our review more than half of the included studies have used an adult patient population. Only nine studies performed research among children with asthma, seven of these are trials on physical exercises. Based on these seven studies, a conclusion can be drawn about the additional value of physical exercises specific in children with asthma, but for breathing exercises and IMT this will be difficult.

Limitations of the review

There are a few limitations with respect to this review. Firstly, the total number of patients in each study is sometimes very small, which makes it unable to detect clinically relevant effect sizes. Secondly, the designs of the randomized controlled trials used in our review are very different. Not only have they used different outcome measures, also the control group, the duration of the training and the content of the training of each study is different. If the same outcome measures are used in different trials, they are often measured in a different way. The duration of the training used in the individual studies on breathing exercises and physical training is very different. A range of four to 28 weeks is seen in breathing exercises (Table 2), for physical exercises six to 16 weeks (Table 4). In addition, training on physical exercises varied in duration and frequency for each trial (Table 4). For example, one group trained 30 min twice a week, another group trained 90 min three times a week. The studies used different control groups, such as usual care, education, other breathing exercises or healthy controls. Through all these different methods it is difficult to compare the various trials, therefore we were not able to pool data of different studies or to make a meta-analysis comparing the results. We were only able to describe results found in the different studies.

In daily practice, physiotherapists mainly use combinations of various techniques. Unfortunately, most randomized controlled trials investigated individual techniques. Only three[11,15,26] of the 21 included trials in our review combined various techniques. Shaw et al.[15] is the only study that compared a combination of techniques with usual care. No significant differences were found between these two groups. In conclusion, there are too few studies that have examined the effectiveness of combinations of these techniques, while this can be very promising.

Conclusion

From this review we may conclude that the three physiotherapy techniques breathing exercises, inspiratory muscle training and physical training can have beneficial effects in asthmatics. The main findings are that these forms of physiotherapy may improve disease specific quality of life, cardiopulmonary fitness and maximal inspiratory pressure and reduce symptoms and medication use. Specifically for children suffering from asthma, we can conclude that physical training may improve disease specific quality of life. Therefore, physiotherapy should be incorporated in the treatment of asthma.

Even though Cochrane reviews have indicated positive effects of physiotherapy in asthma patients only few studies have been published since. Most of the recent studies confirm positive effects. Further studies are needed to confirm the findings from this review. These new studies should investigate whether physiotherapy may play a role in the treatment in both adults and children with asthma. These studies should investigate combinations of physiotherapeutic techniques, including breathing exercises, inspiratory muscle training, physical training and airway clearance, compared to usual care.

Conflict of interest

We declare that we do not have any conflict of interest with respect to above described article.

References

1. Bindels PJ, van der Wouden JC, Ponsioen BP, Brand PL, Salomé PL, Van Hensbergen W, Van Hasselt PA, Steenkamer TA, Grol MH. NHG-Standaard Astma bij kinderen (Tweede herziening). *Huisarts Wet* 2006;**49**:557–72.

2. Global Inititative for Asthma (GINA). *Global strategy for asthma management and prevention* 2011 [update].
3. Geijer RMM, Chavannes NH, Muris JWM, Sachs APE, Schermer T, Smeele IJM, Thoonen B, Van der Molen T, Van Schayck CP, Van Weel C, Kolnaar BGM, Grol MH. NHG-Standaard Astma bij volwassenen (Tweede herziening). *Huisarts Wet* 2007;**50**:537—51.
4. Dennis J. Alexander technique for chronic asthma. *Cochrane Database Syst Rev* 2000;(2). CD000995.
5. Holloway E, Ram FS. Breathing exercises for asthma. *Cochrane Database Syst Rev* 2004;(1). CD001277.
6. Hondras MA, Linde K, Jones AP. Manual therapy for asthma. *Cochrane Database Syst Rev* 2005;(2). CD001002.
7. Ram FS, Robinson SM, Black PN, Picot J. Physical training for asthma. *Cochrane Database Syst Rev* 2005;(4). CD001116.
8. Ram FS, Wellington SR, Barnes NC. Inspiratory muscle training for asthma. *Cochrane Database Syst Rev* 2003;(4). CD003792.
9. Bruton A, Thomas M. The role of breathing training in asthma management. *Curr Opin Allergy Clin Immunol* 2011;**11**:53—7.
10. Turner LA, Turner LA, Mickleborough TD, McConnell AK, Stager JM, et al. Effect of inspiratory muscle training on exercise tolerance in asthmatic individuals. *Med Sci Sports Exerc* 2011;**43**:2031—8.
11. Mendes FA, Gonçalves RC, Nunes MP, Saraiva-Romanholo BM, et al. Effects of aerobic training on psychosocial morbidity and symptoms in patients with asthma: a randomized clinical trial. *Chest* 2010;**138**:331—7.
12. Bott J, Blumenthal S, Buxton M, Ellum S, Falconer C, et al. Guidelines for the physiotherapy management of the adult, medical, spontaneously breathing patient. *Thorax* 2009;**64**: i1—51.
13. van der Giessen LJ, Gulmans VAM, Lucas T, van der Lugt M, Hendriks HJ. KNGF-richtlijn Astma bij kinderen. *Ned Tijdschr Fysioth* 2005;**115**:s1—47.
14. Lima EV, Lima WL, Nobre A, dos Santos AM, et al. Inspiratory muscle training and respiratory exercises in children with asthma. *J Bras Pneumol* 2008;**34**:552—8.
15. Shaw BS, Shaw I. Pulmonary function and abdominal and thoracic kinematic changes following aerobic and inspiratory resistive diaphragmatic breathing training in asthmatics. *Lung* 2011;**189**:131—9.
16. Cowie RL, Conley DP, Underwood MF, Reader PG. A randomised controlled trial of the Buteyko technique as an adjunct to conventional management of asthma. *Respir Med* 2008;**102**: 726—32.
17. Grammatopoulou EP, Skordilis EK, Stavrou N, Myrianthefs P, Karteroliotis K, Baltopoulos G, Koutsouki D. The effect of physiotherapy-based breathing retraining on asthma control. *J Asthma* 2011;**48**:593—601.
18. Holloway EA, West RJ. Integrated breathing and relaxation training (the Papworth method) for adults with asthma in primary care: a randomised controlled trial. *Thorax* 2007;**62**: 1039—42.
19. Slader CA, Reddel HK, Spencer LM, et al. Double blind randomised controlled trial of two different breathing techniques in the management of asthma. *Thorax* 2006;**61**:651—6.
20. Thomas M, McKinley RK, Mellor S, Watkin G. Breathing exercises for asthma: a randomised controlled trial. *Thorax* 2009;**64**:55—61.
21. Chiang LC, Ma WF, Huang JL, Tseng LF, Hsueh KC. Effect of relaxation-breathing training on anxiety and asthma signs/symptoms of children with moderate-to-severe asthma: a randomized controlled trial. *Int J Nurs Stud* 2009;**46**: 1061—70.
22. Meuret AE, Ritz T, Wilhelm FH, Roth WT. Targeting pCO(2) in asthma: pilot evaluation of a capnometry-assisted breathing training. *Appl Psychophysiol Biofeedback* 2007;**32**:99—109.
23. Sodhi C, Singh S, Dandona PK. A study of the effect of yoga training on pulmonary functions in patients with bronchial asthma. *Indian J Physiol Pharmacol* 2009;**53**:169—74.
24. Moreira A, Delgado L, Haahtela T, Fonseca J, et al. Physical training does not increase allergic inflammation in asthmatic children. *Eur Respir J* 2008;**32**:1570—5.
25. Basaran S, Guler-Uysal F, Ergen N, Seydaoglu G, et al. Effects of physical exercise on quality of life, exercise capacity and pulmonary function in children with asthma. *J Rehabil Med* 2006;**38**:130—5.
26. Mendes FA, Almeida FM, Cukier A, Stelmach R, et al. Effects of aerobic training on airway inflammation in asthmatic patients. *Med Sci Sports Exerc* 2011;**43**:197—203.
27. Turner S, Eastwood P, Cook A, Jenkins S. Improvements in symptoms and quality of life following exercise training in older adults with moderate/severe persistent asthma. *Respiration* 2011;**81**:302—10.
28. Fanelli A, Cabral AL, Neder JA, Martins MA. Exercise training on disease control and quality of life in asthmatic children. *Med Sci Sports Exerc* 2007;**39**:1474—80.
29. Flapper BC, Duiverman EJ, Gerritsen J, Postema K, van der Schans CP. Happiness to be gained in paediatric asthma care. *Eur Respir J* 2008;**32**:1555—62.
30. Wang JS, Hung WP. The effects of a swimming intervention for children with asthma. *Respirology* 2009;**14**:838—42.
31. Wicher IB, Ribeiro MA, Marmo DB, Santos CI. Effects of swimming on spirometric parameters and bronchial hyperresponsiveness in children and adolescents with moderate persistent atopic asthma. *J Pediatr* 2010;**86**:384—90.
32. Onur E, Kabaroğlu C, Günay O, Var A, et al. The beneficial effects of physical exercise on antioxidant status in asthmatic children. *Allergol Immunopathol* 2011;**39**:90—5.