Review

Effects of physical training in asthma: a systematic review

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Abstract
***Objectives*—To assess the evidence for the effects of physical training on pulmonary function, symptoms, cardiopulmonary fitness, and quality of life in subjects with asthma.**
***Methods*—A search was conducted for randomised controlled trials of subjects with asthma undertaking physical training using the Cochrane Airways Group register of controlled clinical trials, Medline, Embase, Sportdiscus, Science citation index, and Current contents index. Studies were included in the review if the subjects had asthma, were 8 years of age or older, and had undertaken physical training for at least 20 minutes per session, twice a week, for a minimum of four weeks. The eligibility of trials for inclusion in the review and the quality of the trials were independently assessed by two reviewers.**
***Results*—Eight studies with a total of 226 subjects met the inclusion criteria for this review. Physical training had no effect on resting lung function but led to an improvement in cardiopulmonary fitness as measured by an increase in maximum oxygen uptake of 5.6 ml/kg/min (95% confidence interval 3.9 to 7.2). None of the studies measured quality of life.**
***Conclusions*—Physical training improves cardiopulmonary fitness without changing lung function. It is not clear if the improvement in fitness translates into a reduction in symptoms or an improvement in the quality of life. There is a need for further randomised controlled trials of the effects of physical training in the management of asthma.**
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Keywords: asthma; physical training; fitness; randomised controlled trials; meta-analysis

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Subjects with asthma have a unique response to physical activity. On the one hand, exercise can provoke an increase in airways resistance leading to exercise induced asthma. On the other, regular physical activity and participation in sports are considered to be useful in the management of asthma, especially in children and adolescents,[1] but this has not been investigated in the same detail as the mechanisms of exercise induced asthma.

Exercise induced asthma can be prevented or reduced by pretreatment with a number of medicines including β agonists, chromones, and leukotriene antagonists. Despite this, the fear of inducing an episode of breathlessness inhibits many patients with asthma from taking part in physical activity. A low level of regular physical activity in turn leads to a low level of physical fitness, so it is not surprising that a number of studies[2 3] have found that patients with asthma have lower cardiorespiratory fitness than their peers, although not every study has reported this.[4]

Physical training programmes have been designed for patients with asthma with the aim of improving physical fitness, neuromuscular coordination, and self confidence. Subjectively, many patients report that they are symptomatically better when fit, but the physiological basis of this perception has not been systematically investigated. A possible mechanism is that an increase in regular physical activity of sufficient intensity to increase aerobic fitness will raise the ventilatory threshold, thereby lowering the minute ventilation during mild and moderate exercise. Consequently breathlessness and the likelihood of provoking exercise induced asthma will both be reduced. Exercise training may also reduce the perception of breathlessness through other mechanisms including strengthening of the respiratory muscles.

We have conducted a systematic review to measure the effects of physical training on subjects with asthma. This review was conducted for the Cochrane Collaboration. With these reviews, every effort is made to locate all published and unpublished studies (without any restriction on language) to answer the question. Explicit criteria are used to select studies for inclusion in the review and to assess their quality. If appropriate, a meta-analysis is used to produce an overall result. Meta-analysis is a statistical procedure to quantitatively summarise the results of randomised controlled trials.

Objectives

This review was undertaken to gain a better understanding of the effects of physical training on the health of subjects with asthma. The objective was to assess the evidence from

Table 1 Characteristics of excluded studies

Study	*Reason for exclusion*
Graff-Lonnevig *et al*[6]	Study was not truly randomised. Allocation was based on who lived closer to the gymnasium and this group was included in the exercise training arm.
Cambach *et al*[7]	Study included a composite intervention and included both subjects with asthma and chronic obstructive pulmonary disease. A physiotherapist run programme included breathing retraining, mucus evacuation, and exercise.
Svenonius *et al*[8]	Not randomised as the subjects could choose which group they would like to belong to for the study.
Bundgaard *et al*[9]	Both the groups were trained and the only difference was the intensity of training with no difference in duration or frequency of training.
Dean *et al*[10]	The study was too short, being only for 5 days.
Edenbrandt *et al*[11]	Frequency of physical training was low, subjects only exercised once a week.
Orenstein *et al*[12]	Not truly randomised, subjects were assigned to groups according to the availability of transport.
Hirt *et al*[13]	Mentioned as randomised, but all patients who were in hospital were assigned to the group. Subjects who had severe asthma were assigned to the control group.
Henriksen *et al*[14]	Subjects were said to be randomly chosen but the intervention group of 28 were chosen from a total of 42 because they were inactive in sports and physical games and had poor physical fitness. Control groups were more physically active than the subjects in the intervention group.
Neder *et al*[15]	Not truly randomised, subjects were assigned to groups consecutively. First 26 subjects entered the training group and the next 16 subjects had no training.

randomised controlled clinical trials of the effects of physical training on resting pulmonary function, aerobic fitness, clinical status, and quality of life in asthmatics.

Methods

TYPES OF STUDY AND PARTICIPANTS

Only trials of subjects with asthma who were randomised to physical training or a control intervention were selected. Subjects had to be aged 8 years or older and their asthma had to be diagnosed by a doctor or by the use of objective criteria—for example, bronchodilator reversibility. Subjects with any degree of asthma severity were included. To qualify for inclusion, the physical training had to include whole body aerobic exercise for at least 20 minutes, two or more times a week, for a minimum of four weeks.

SEARCH STRATEGY

The following terms were used to search for studies: asthma AND (work capacity OR physical activity OR training OR rehabilitation OR physical fitness). The Cochrane Collaboration asthma and wheeze randomised controlled clinical trials register (up to August 1999) was searched for studies. Additional searches were carried out on Medline (1966–1999), Embase (1980–1999), Sportdiscus (1949–1999), Current contents index (1995–1999), and Science citation index (1995–1999). The reference lists of all the papers obtained were reviewed to identify trials not captured by electronic and manual searches. Abstracts were reviewed without language restriction. When more data were required for the systematic review, the authors of the study were contacted and asked to provide the additional information or clarification.

Data sources, inclusion criteria, and outcomes

- Eighteen randomised controlled trials of physical training of patients with asthma were identified in the literature covering the years 1966 to 1999.
- Eight of these trials met the inclusion criteria: objective asthma diagnosis, age (⩾8 years), and at least 20 minutes whole body exercise on two or more times a week for a minimum of four weeks.
- The outcomes of interest, resting lung function, asthma state, and cardiorespiratory fitness, were subjected to a meta-analysis.

DATA COLLECTION AND ANALYSIS

The following outcome measures were looked for: bronchodilator usage, episodes of wheeze,

Table 2 Characteristics of included studies

Study	*Method of participant selection*	*Description of participants and duration of physical training.*	*Type of physical training*
Sly *et al*[16]	Participants were selected from patients attending a paediatric allergy clinic at a hospital.	Children aged between 9 and 13 years. Sessions were for 2 hours three days a week, 39 sessions in total.	Swimming, calisthenics, tumbling, parallel bars, rope climbing, abdominal strengthening, wall ladder and running.
Ahmaidi *et al*[17]	Participants were selected after performing incremental exercise test on a cycle ergometer and the 20 m shuttle test.	Children aged between 12 and 17 years. Sessions were for one hour, three days a week for three months, 36 sessions in total.	Running on an outdoor track.
Cochrane *et al*[18]	Six week run-in period preceded patient selection.	Participants aged 16–40 years. Sessions lasted 30 min, three days a week for 3 months.	Warm-ups, cycling, jogging, light-calisthenics, stretching and aerobics.
Swann *et al*[19]	Participants attending an asthma clinic with >20% fall in FEV_1 were selected.	Children aged between 8 and 14 years. Sessions were twice a week and lasted for 3 months.	Warm-ups, squat thrusts, star jumps, sit-ups and press-ups.
Varray *et al*[20]	Participants selected if a 15% improvement in FEV_1 by inhaling a bronchodilator.	Children mean age 10.3 years (exercise) and 11.7 years (control). Sessions lasted 30 min each, were twice a week for 3 months, 30 sessions in total.	Indoor swimming pool used with individualised training intensity.
Varray *et al*[21]	Participants had to meet 3 of 4 criteria: clinical, allergic, immunological, and functional (>15% increase in FEV_1).	Children mean age 11.4 years. Sessions lasted for an hour each with 10 min on and 10 min off training.	Indoor swimming pool training.
Fitch *et al*[22]	The 1962 American Thoracic Society definition of asthma was used for selection.	Children aged between 10 and 14 years. Physical training period was for 3 months.	Jogging, calisthenics, soccer, netball, volleyball, sprints.
Girodo *et al*[23]	Media solicitation was used to obtain volunteers.	Participant age was between 28 and 33 years. Subjects trained for one hour, 3 times a week for 16 weeks.	No details provided in published paper, but the subjects were led by a person experienced in physical education.

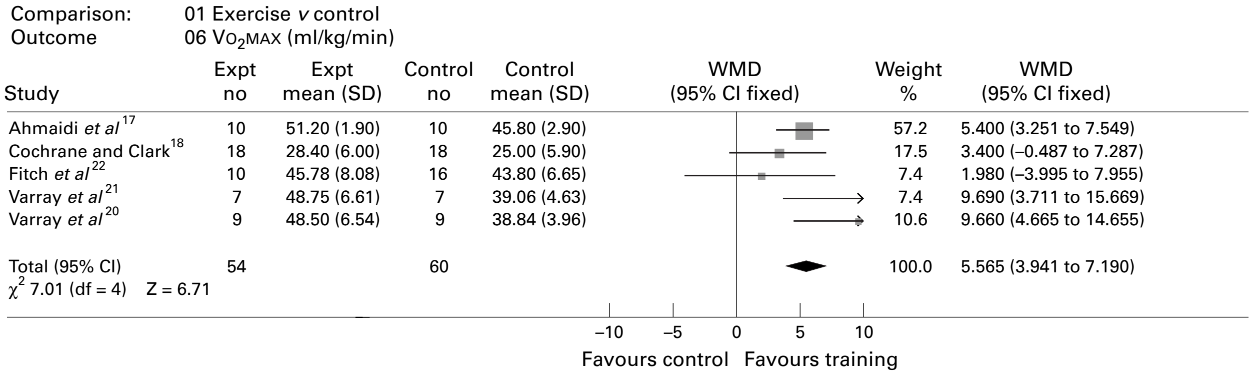

Figure 1 Details of $\dot{V}O_2$MAX (ml/kg/min) outcome. The mean value for each trial is indicated by a square box with the line through it representing the 95% confidence interval (CI). Mean values left of the zero effect line (0) favour control and values on the right favour physical training. The solid diamond indicates the overall mean effect that physical training has on $\dot{V}O_2$MAX. A percentage weighting (Weight %), which is dependent on the precision and sample size of the estimation of the mean value for each randomised controlled trial, is allocated to each study. The χ^2 (7.01) and the degrees of freedom (df = 4) values at the bottom left give a measure of heterogeneity of the combined results that contributed towards the overall mean result for $\dot{V}O_2$MAX. The Z statistic (6.71) indicates the level of significance for the overall result.

symptoms (recorded in daily diary cards), exercise endurance, work capacity, walking distance, measures of quality of life, and physiological measurements—that is, peak expiratory flow rate, forced expiratory volume in one second, forced vital capacity, $\dot{V}O_2$MAX, $\dot{V}$EMAX, maximum heart rate, maximum voluntary ventilation. Two reviewers (F S F R and S M R) assessed the trials for inclusion by only looking at the methods section of each paper without reading the results of the study or the conclusions.[5] Each reviewer independently applied written inclusion/exclusion criteria to the methods section of each study. Disagreement about inclusion of a study was resolved whenever possible by consensus, and the third reviewer (P N B) was consulted if disagreement persisted. All trials that appeared to be potentially relevant were assessed, and if appropriate were included in the review. If a randomised controlled trial was excluded on methodological grounds, the reason for exclusion was recorded (table 1).

The methodological quality of the included trials was assessed with particular emphasis on allocation concealment, which was ranked using the Cochrane Collaboration approach: grade A, adequate concealment; grade B, uncertain; grade C, clearly inadequate concealment; grade D, not used (no attempt at concealment).

Two of the reviewers independently extracted data from the trials. The trials were combined for meta-analysis using Review Manager 4.0.4 (Cochrane Collaboration). A fixed effects model was used. The outcomes of interest in this review were continuous data. Data from each of the continuous outcomes were analysed as weighted mean difference with 95% confidence intervals.

Results

The electronic search yielded 690 potential studies: 25 references were found in Embase, 82 in Medline, 76 in Sportdiscus, and 507 were obtained from the Cochrane Collaboration asthma and wheeze randomised controlled clinical trials database. An additional 28 references were added from bibliographic searching of relevant articles. Of a total of 718 abstracts, 47 dealt with physical training in asthma. The full text of each of the 47 papers was obtained and translated where necessary (one each from French and German). Eighteen randomised controlled trials were potentially suitable for inclusion. Ten[6–15] were excluded for the reasons detailed in table 1, and the remaining eight[16–23] were eventually included in this systematic review (table 2).

We wrote to the first authors of the included studies to clarify areas of uncertainty. Most of the trials did not describe the method of randomisation and did not make any references to allocation concealment (blinding). All trials mentioned that subject allocation was carried out randomly but none mentioned the method of randomisation. Using the Cochrane Collaboration approach for allocation concealment, all trials included in this review were allocated a grade B, indicating that we were uncertain as to the method of randomisation used by the authors in their trials.

Table 3 Summary mean result for each outcome

Outcome measure	*Weighted mean difference*	*95% confidence interval*	*Number of studies contributing to outcome (study reference)*
PEFR (litres/min)	−2.43	−43.98 to 39.11	2 (16 and 22)
FEV_1 (litres/min)	−0.16	−0.40 to 0.07	3 (16, 18 and 21)
FVC (litres)	−0.22	−0.68 to 0.23	2 (16 and 21)
$\dot{V}$EMAX (litres/min)	4.79	−2.78 to 12.38	2 (18 and 21)
$\dot{V}O_2$MAX (ml/kg/min)	5.57	3.94 to 7.19	5 (17, 18, 20, 21 and 22)
Work capacity (W)	28.00	22.57 to 33.43	1 (17)
HRMAX (bpm)	3.64	0.99 to 6.28	3 (17, 21 and 22)
Episodes of wheeze (days)	−7.50	−22.42 to 7.42	1 (16)

The study reference is the reference number.
PEFR, peak expiratory flow rate; FEV_1, forced expiratory volume in one second; FVC, forced vital capacity; HRMAX, maximum heart rate. $\dot{V}$EMAX, maximum expiratory flow.

Main findings

- Physical training resulted in a significant increase in cardiorespiratory fitness as measured by an increase in the $\dot{V}O_2$MAX.
- Work capacity (W) was also significantly increased in one of these studies.
- There was no effect of physical training on resting lung function.
- No data were available on measures of quality of life.

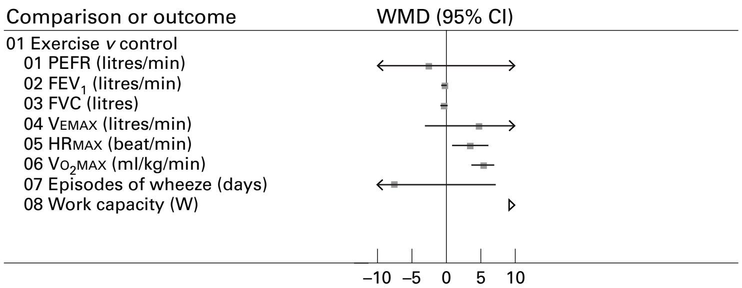

Figure 2 Overall meta-analytical results. Mean value for each outcome is indicated by a square box with the line through it representing the 95% confidence interval (CI). Mean values left of the zero effect line (0) favour control and values on the right favour physical training, except for negative outcomes (where a decrease in the outcome is "good"—for example, episodes of wheeze and maximum heart rate) where mean values left of the zero effect line favour training. A weighted mean difference (WMD) is allocated for each study, which is a method of the meta-analysis used to combine measures on continuous scales. PEFR, peak expiratory flow rate; FEV_1, forced expiratory volume in one second; FVC, forced vital capacity; HRMAX, maximum heart rate.

Figure 1 shows how the effect of physical training on VO_2MAX was assessed. The mean and standard deviation is shown for the experimental group (physical training group) and the control group for each of the five studies in which VO_2MAX was measured. On the right hand side of fig 1 the weighted mean difference is shown. This is the difference between the experimental and control groups, weighted according to the precision of the study in estimating the effect. With the statistical software used here (RevMan 4.0.4), this is the inverse of the variance. This method assumes that all of the trials have measured the outcome on the same scale and that for each study the baseline VO_2MAX was not significantly different between control and experimental groups. Where the weighted mean difference lies to the right of the line of zero effect, it favours physical training. If the 95% confidence interval does not cross the line of zero effect, the result is statistically significant. The overall weighted mean difference (95% confidence interval) for the five studies was 5.57 ml/kg/min (3.94 to 7.19), represented by the diamond at the bottom of the figure—that is, physical training resulted in an increase in VO_2MAX of 5.57 ml/kg/min.

The χ^2 value (7.01) gives an indication of the heterogeneity of the studies. The test of heterogeneity shows whether or not the differences in the results of the five studies are greater than would be expected by chance. In this case the χ^2 value has to be greater than 9.49 (4 degrees of freedom and $\alpha = 0.05$) before the studies would be considered heterogeneous. For VO_2MAX it is 7.01 and therefore it can be concluded that the randomised controlled trials contributing to this particular outcome were not heterogeneous. This was true for all outcome measures reported in this review.

Table 3 provides a summary of the results. The overall weighted mean difference is shown for each of the outcome measures along with the 95% confidence intervals. Physical training led to a significant increase in VO_2MAX (five studies) and work capacity (one study). Figure 2 depicts these results graphically.

Episodes of wheeze were reported in only one study.[16] Although the number of episodes of wheeze was 7.5 days less in the training group, this difference was not significant ($p = 0.3$).

No data were available for the following outcome measures: maximum voluntary ventilation, bronchodilator use, symptom diary scores, exercise endurance, walking distance, or measures of quality of life. There were insufficient studies to justify subgroup analysis by sex, age, or exercise intensity.

Discussion

The clearest finding of this meta-analysis was that aerobic power (VO_2MAX) increased with physical training. This shows that the response of subjects with asthma to physical training is similar to that of healthy people,[24] and therefore presumably the benefits of an increase in cardiorespiratory fitness are also accessible to them. Work capacity—that is, the maximum work output—was only measured in one study, but it was also increased, which is consistent with the observation that VO_2MAX is increased.

No improvement in resting lung function was shown. This is not surprising, as there is no obvious reason why regular exercise should improve peak expiratory flow rate or forced expiratory volume in one second. Any benefits of regular exercise in patients with asthma are unrelated to effects on lung function.

Typically, physical training has no effect or slightly reduces the maximum heart rate whereas maximum stroke volume, and thus maximum cardiac output, are increased.[25 26] In the studies included in this review, maximum heart rate increased after physical training.[17 18 22] This suggests that cardiac factors did not limit the maximum exercise capacity before training. Breathlessness or some other non-cardiac factor may have terminated the baseline tests before a true maximum heart rate was achieved. The higher heart rate after physical training may reflect the ability of subjects to exercise for longer.

An alternative explanation, which is improbable, is that the medication taken to prevent exercise induced asthma caused the increased maximum heart rate. Inhaled β agonists can raise heart rate above resting levels but prophylactic medication was not changed during the study period and there is no evidence that physical training alters the cardiac response to β agonists. The significance of the effect of these agents on heart rate lies in their alteration of the workload-heart rate relation and the possible consequences of this for exercise prescription based on heart rate.

Unfortunately, no data were available on a number of outcome measures of interest for this review—that is, exercise endurance (as distinct from VO_2MAX), symptoms (other than frequency of wheeze), bronchodilator use, and measures of quality of life. This review has disclosed an important gap in our knowledge about the effects of physical training in asthma. There is, however, evidence from one study,[7] which was excluded from this review, suggesting that physical training may improve these outcomes. The study by Cambach *et al*[7] included subjects with asthma, but was not included in our review because they also received education about their disease and breathing retraining. This means that any benefit could not be ascribed solely to physical training. Nonetheless the intervention resulted in significant improvements in exercise endurance time, and the total score for the chronic respiratory disease questionnaire increased by 17 points compared with the control group. In subjects with chronic obstructive pulmonary disease, pulmonary rehabilitation does not lead to an improvement in these parameters unless the subjects undertake exercise training,[27] and the same may be true of asthma. A recent study from Brazil[15] allocated children to physical training or a control group. The study was not included in the review because the allocation of the subjects was not truly random, but it did find that physical training led to significant reductions in the use of both inhaled and oral steroids.

There are a number of pitfalls in conducting systematic reviews. Electronic searches of the literature may identify as few as 50% of the relevant studies.[28] Hand searching of journals may be useful to increase the yield but is labour and time intensive. The Cochrane Collaboration asthma and wheeze randomised controlled trials register incorporates systematic hand searching (retrospective and prospective) of 20 core journals in respiratory disease in an attempt to improve the thoroughness of electronic searching in this area. So that we did not miss any relevant papers, we used several electronic databases in addition to the asthma and wheeze randomised controlled trials register, and we checked the reference lists of all the papers we obtained to identify studies we had not already found. This approach will have reduced our chance of missing relevant studies.

Another source of bias can be with the selection of the relevant studies from the titles and abstracts of papers. This source of bias was reduced by having written inclusion and exclusion criteria and by having two people independently review and select the papers from the abstracts of the 718 studies identified.

The review was restricted to randomised controlled trials. This eliminated a substantial source of data, but this approach is justified because the strength of the evidence obtained from randomised controlled trials is much greater than that obtained from other studies. Adequate randomisation technique and allocation concealment have been found to be important aspects of good quality trials. We attempted to assess the quality of randomisation technique and allocation concealment in the studies that we included in the review. Unfortunately, few of the studies provided information about this, other than stating that the subjects were randomised to physical training or control groups.

A potential weakness of this review is the small number of subjects included. However, the studies that measured $V\text{O}_2$MAX were homogeneous and all studies showed a similar effect, which was highly significant ($p = 0.001$).

In summary, one can conclude that aerobic power improves after physical training in patients with asthma. This appears to be a normal training effect and is not due to an improvement in resting lung function. There is a need, however, for further randomised controlled trials to assess the role of physical training in the management of bronchial asthma. In particular, it will be important to determine whether the improved exercise performance that follows physical training is translated into fewer symptoms and to an improvement in the quality of life.

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Multiple choice questions (one correct answer only)

1 In people with asthma, regular physical training leads to improvements in:
(a) forced expiratory volume in one second
(b) vital capacity
(c) peak expiratory flow rate
(d) maximal oxygen uptake
(e) bronchial hyper-responsiveness

2 For systematic reviews of clinical trials to be reliable they should not include:
(a) unpublished studies
(b) open uncontrolled studies
(c) non-English language studies
(d) small studies
(e) large studies

3 In subjects with asthma there is clear evidence that:
(a) β_2 agonists should not be used before exercise
(b) physical training reduces the quality of life
(c) many types of physical training improve aerobic fitness
(d) physical training should be restricted to children under the age of 12 years
(e) only swimming improves aerobic fitness

4 Physical training of asthmatic people has been shown to:
(a) reduce the need for bronchodilator use
(b) reduce the incidence of exercise induced asthma
(c) increase the maximum voluntary ventilation
(d) increase the maximum exercise ventilation
(e) increase maximum work capacity

5 The Cochrane Collaboration:
(a) prepares and maintains systematic reviews of the effects of health care interventions
(b) is a collection of historical medical biographies
(c) disseminates information about non-scientific treatments for human diseases and disorders
(d) maintains a database on the epidemiology of asthma
(e) is a non-profit organisation which sponsors research into alternative treatments for asthma

Essay questions

- Discuss the advantages and disadvantages of systematic reviews of randomised controlled trials in summarising evidence of the effectiveness of health care interventions.
- Write an essay on the role and benefits of physical training for patients with asthma.

Take home message

Having asthma need not prevent a patient from obtaining the benefits of increased physical activity. This review shows that people with asthma who take regular exercise can improve their cardiorespiratory fitness and work capacity. Further studies are necessary to determine if regular exercise reduces symptoms and improves the quality of life in asthma.

The Cochrane Collaboration and the Cochrane Airways Group

The Cochrane Collaboration is an international network of individuals and institutions which evolved to prepare systematic periodic reviews of randomised controlled trials. Individual trials may be too small to answer questions on the effects of health care interventions. Systematic reviews that include all relevant studies reduce bias and increase statistical power and make it easier to determine if a treatment is effective or not. With the exponential growth of the medical literature (over two million articles are published annually), systematic reviews help to distill this information down and make it more manageable.

The Cochrane Collaboration is organised into 47 review groups including the Airways Group which was established to prepare reviews on asthma and chronic obstructive pulmonary disease. Before the reviews are published electronically in the Cochrane Library they are peer reviewed. Reviews are then updated at regular intervals. The Airways Group has 211 active reviewers and has completed 39 reviews. Another 86 reviews are in progress. More information about the Cochrane Collaboration including abstracts of the reviews can be found at: www.cochrane.org. The full text of reviews are available on subscription either on the internet or on CD-ROM (www.update-software.com/cochrane.htm).