Effect of Air Filtration Systems on Asthma: A Systematic Review of Randomized Trials

Ellen McDonald, Deborah Cook, Toni Newman, Lauren Griffith, Gerard Cox and Gordon Guyatt

*Chest* 2002;122;1535-1542
DOI 10.1378/chest.122.5.1535

The online version of this article, along with updated information and services can be found online on the World Wide Web at: [http://chestjournal.org/cgi/content/abstract/122/5/1535](http://chestjournal.org/cgi/content/abstract/122/5/1535)
Effect of Air Filtration Systems on Asthma

A Systematic Review of Randomized Trials

Ellen McDonald, RN; Deborah Cook, MD, FCCP; Toni Newman, BA; Lauren Griffith, MS Biostatistics; Gerard Cox, MD; and Gordon Guyatt, MD, FCCP

Study objectives: To systematically review the evidence of randomized trials evaluating the effects of residential air filtration systems on patients with asthma.

Data sources: We searched for published and unpublished studies using MEDLINE, the Cumulative Index to Nursing and Allied Health Literature, and the Cochrane Collaboration. We reviewed all reference lists for additional articles of relevance, and contacted experts in the field and air filter manufacturers.

Study selection: We identified 10 relevant randomized controlled trials that examined the influence of a residential air filtration system on patients with asthma.

Data extraction: In duplicate and independently, we abstracted data on the methodologic quality, population, intervention, and outcomes.

Data synthesis: Five of 10 studies enrolled adults only. One study included children only. The sample size ranged from 9 to 45 participants in each study, for a total of 216 patients across all studies. Two studies reported a statistically significant decrease in airway responsiveness associated with air filter utilization. Air filters were associated with significantly lower total symptom scores (weighted mean difference of 0.47; 95% confidence interval [CI], 0.69 to 0.25) on a 10-point scale, and lower sleep disturbance score (weighted mean difference of 0.93; 95% CI, 1.44 to 0.42); however, heterogeneity of results weakens the inferences from these trials. Air filtration systems were not associated with any differences in medication use or morning peak expiratory flow values. None of these trials employed validated scales to measure clinical symptoms or quality of life.

Conclusions: Among patients with allergies and asthma, use of air filters is associated with fewer symptoms. Rigorous sufficiently powered randomized clinical trials are needed to more precisely define the influence of air filtration on health-related quality of life and symptom control for asthmatic patients.

Key words: air filtration system; air quality; allergy; asthma; environment; quality of life

Abbreviations: CI = confidence interval; HEPA = high-efficiency particulate air; PEF = peak expiratory flow

Asthma is a prevalent and disabling disease worldwide. The prevalence of asthma has markedly increased over the past 2 decades in adults and in children. Habbick et al estimated a lifetime prevalence of asthma among children in two Canadian cities to be 19%.

The cornerstone of asthma management is administration of anti-inflammatory medications and bronchodilators. In addition, there are adjunctive therapies that may contribute to the overall control of asthma. Some of these therapies, despite showing early promise, have not always proved effective. A Cochrane Collaboration systematic review has shown that limited asthma education is unlikely to improve health outcomes in adults. However, interactive education is more effective in changing the behavior of clinicians and patients than passive education. Alternative interventions also demonstrated to be ineffective include chiropractic manipulation.

For editorial comment see page 1509
Public concern has been raised recently about environmental influences on asthma control. The National Institutes of Health guidelines for the diagnosis and management of asthma address indoor and outdoor air quality. The Canadian Asthma Consensus Conference panel concluded that indoor irritants, particularly tobacco smoke, represent a greater health risk than outdoor air pollutants. Among several environmental interventions, indoor air filters appear to be effective in reducing some airborne irritants. The high-efficiency particulate air (HEPA) filter has higher efficiencies for both larger and smaller particles than other filters, with a minimal particle removal efficiency of 99.97% for particles of > 0.3 μm in diameter. The HEPA filter has been associated with reduced airborne levels of cat allergen in a case-control study of 50 homes with a cat and 50 homes without a cat. Other observational studies have shown that HEPA filters reduce the burden of particles from mold spores and cigarette smoke.

In 1992, a narrative review recommended that patients with severe allergies or asthma should use an air-filtering vacuum cleaner and an air cleaner with a HEPA filter. However, the influence of air filtration on patient-centered outcomes has not been established. Evidence about the use of residential air cleaners was graded as level 3C by the 1999 Canadian Asthma Consensus Conference, indicating "poor evidence to support a recommendation for or against use." Subsequently, investigators have suggested that future research should address the influence of improving air quality on asthma control. The objective of this systematic review is to critically appraise and summarize the current randomized trial evidence about the effect of residential air filters on signs and symptoms of asthma, and to inform patients, clinicians, and researchers of our findings.

### Materials and Methods

#### Data Sources

We searched the computerized databases MEDLINE and Cumulative Index to Nursing and Allied Health Literature from 1976 to 2000 using the following text words and key words: "asthma," "quality of life," "air filter," "indoor air quality," and "randomized controlled trials." We also searched the Cochrane Collaboration Trials Registry. To identify additional potentially relevant studies, we corresponded with experts in the field of asthma research, manufacturers of air filtration systems, and the authors of the primary studies included in this review. We also reviewed the citation lists or bibliographies of all the relevant studies and reviews, and retrieved any article that looked relevant to this systematic review. We had no language restrictions.

#### Study Selection

Using criteria determined a priori, two of the authors (E.M., T.N.) independently reviewed the first literature search to identify primary research studies that addressed the question posed. Based on title and abstract, all citations identified as potentially relevant by either reviewer were then retrieved for full review. To be included in the systematic review, the studies needed to meet the following criteria: (1) design, randomized controlled trials; (2) population, children or adults with a diagnosis of asthma; (3) intervention, use of a residential air filtration system; and (4) patient-oriented outcomes, as reported in each study such as asthma signs and symptoms, physiologic, laboratory, and other end points (ie, measurement and documentation of particulate). We did not consider observational studies, surveys, asthma classification documents, and practice guidelines for this review. We excluded studies of patients with poor asthma control following hospitalization.

#### Data Extraction: Validity Assessment and Clinical Characteristics

In duplicate, independently, we abstracted data to describe the methodologic quality and clinical characteristics of these trials. Methodologic features we report include the method of treatment allocation, masking of treatment allocation (concealment),

<table>
<thead>
<tr>
<th>Source</th>
<th>Design</th>
<th>Concealment</th>
<th>Blinding of Patients</th>
<th>Blinding of Outcome Assessors</th>
<th>Postrandomization Exclusions</th>
<th>Intent-to-Treat Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zweemer et al²⁰ (1973)</td>
<td>RCT crossover</td>
<td>NR</td>
<td>Yes</td>
<td>Yes</td>
<td>6 of 18 excluded</td>
<td>No</td>
</tr>
<tr>
<td>Villaveces et al²¹ (1977)</td>
<td>RCT crossover</td>
<td>NR</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Kooistra et al²² (1978)</td>
<td>RCT crossover</td>
<td>NR</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes for symptoms, no for allergens</td>
</tr>
<tr>
<td>Verral et al²³ (1988)</td>
<td>RCT crossover</td>
<td>NR</td>
<td>Yes</td>
<td>Yes</td>
<td>3 of 16 excluded</td>
<td>No</td>
</tr>
<tr>
<td>Reisman et al²⁴ (1990)</td>
<td>RCT crossover</td>
<td>NR</td>
<td>Yes</td>
<td>Yes</td>
<td>11 of 40 excluded</td>
<td>No</td>
</tr>
<tr>
<td>Antonicelli et al²⁵ (1991)</td>
<td>RCT crossover</td>
<td>NR</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Warburton et al²⁶ (1994)</td>
<td>RCT crossover</td>
<td>NR</td>
<td>Yes</td>
<td>Yes</td>
<td>1 of 13 excluded</td>
<td>No</td>
</tr>
<tr>
<td>van der Heide et al²⁷ (1997)</td>
<td>RCT</td>
<td>NR</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Wood et al²⁸ (1998)</td>
<td>RCT</td>
<td>NR</td>
<td>Yes</td>
<td>Yes</td>
<td>3 of 38 excluded</td>
<td>No</td>
</tr>
<tr>
<td>van der Heide et al²⁹ (1999)</td>
<td>RCT crossover</td>
<td>NR</td>
<td>Yes</td>
<td>Yes</td>
<td>2 of 22 excluded</td>
<td>No</td>
</tr>
</tbody>
</table>

*RCT = randomized clinical trial; NR = not reported.
†Two patients enrolled twice.
<table>
<thead>
<tr>
<th>Source (Funding)</th>
<th>Population</th>
<th>Duration of Exposure (Total)</th>
<th>Treatment Assignment</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zwemer and Karibo* (not reported)</td>
<td>Symptomatic asthmatics 6 to 16 yr old (n = 18)</td>
<td>2 wk (4 wk)</td>
<td>1. Hyposensitization via avoidance and containment methods plus laminar airflow HEPA filter</td>
<td>Significantly less uninterrupted sleep (p ≤ 0.001), lower overall symptom scores (p ≤ 0.001), and lower daytime wheezing scores (p = 0.006)</td>
</tr>
<tr>
<td>Villaveces et al* (Environco Company)</td>
<td>Asthmatics 7 to 15 yrs old (n = 13)</td>
<td>2 wk (4 wk)</td>
<td>1. Hyposensitization and education with or without cromolyn sodium plus laminar HEPA filter</td>
<td>Significantly fewer symptoms (awakening, wheeze, cough, dyspnea, sputum, asthma attacks, rhinitis, restrictive activity, or medication use)</td>
</tr>
<tr>
<td>Kooistra et al* (not reported)</td>
<td>Hay fever or asthma patients 15 to 68 yr old (n = 20)</td>
<td>4 wk (8 wk)</td>
<td>1. HEPA filter</td>
<td>No difference in daytime sneezing, nasal congestion, itchy eyes, or medication use</td>
</tr>
<tr>
<td>Verral et al* (Ontario Ministry of Health, Hepacron, Inc)</td>
<td>Asthmatics with primarily house dust mite allergy 7 to 27 yr old (n = 13)</td>
<td>3 wk (12 wk)</td>
<td>1. HEPA filter</td>
<td>No difference in symptoms, IgE, or PEF</td>
</tr>
<tr>
<td>Reisman et al* (Environmental Air Controls, Inc)</td>
<td>Rhinitis or asthma patients 16 to 61 yr old (n = 29)</td>
<td>4 wk (8 wk)</td>
<td>1. HEPA filter</td>
<td>No difference in congestion, discharge, eye irritation, cough, airway twitching, asthma, or medication use</td>
</tr>
<tr>
<td>Antonicelli et al* (Anallergo-Firenza, Italy)</td>
<td>Mild asthmatics with rhinitis 10 to 28 yr old (n = 9)</td>
<td>8 wk (16 wk)</td>
<td>1. HEPA and home cleaning</td>
<td>No difference in rhinitis, cough, dyspnea, or use of salbutamol or terfenadine</td>
</tr>
<tr>
<td>Warburton et al* (National Safety Associates of America)</td>
<td>Asthmatics 19 to 64 yr old (n = 12)</td>
<td>HEPA, 30.3 d; sham, 24.0 d</td>
<td>1. HEPA filter</td>
<td>No differences in FEV₁, FVC and PEF, serum IgE, eosinophils, skin tests, airway hyperresponsiveness</td>
</tr>
<tr>
<td>van der Heide et al* (Phillips Domestic Appliances and Personal Care)</td>
<td>Allergic asthmatics 18 to 45 yr old (n = 45)</td>
<td>6 mo</td>
<td>1. HEPA filter alone</td>
<td>No differences in FEV₁, FVC and PEF, serum IgE, eosinophils, skin tests, airway hyperresponsiveness</td>
</tr>
<tr>
<td>Wood et al* (Honeywell Corporation, Eudowood Foundation of Maryland)</td>
<td>Cat-allergic adults with asthma or allergic rhinitis 18 to 65 yr old (n = 35)</td>
<td>3 mo</td>
<td>1. HEPA filter</td>
<td>No difference in congestion, rhinorrhea, sneezing, cough, wheezing, chest tightness, sleeping difficulty, or medication use</td>
</tr>
</tbody>
</table>

*PD<sub>20</sub> = provocotive dose of methacholine causing a 20% fall in FEV₁; RAST = radioallergosorbent test.
blinding of the patients, clinicians and outcome assessors, whether co-interventions were described, the proportion of patients who were excluded after randomization, and intention-to-treat analysis. We also report source of funding. Clinical characteristics we report include the population, sample size, duration of exposure, and outcomes. Differences between abstractors were resolved by consensus.

Data Synthesis

Symptoms and medication use were originally reported in different units in each trial, precluding combining these data as reported. To address this issue, we transformed and standardized these data to allow for comparison across the trials.18 To combine individual symptom results from each study, we created a total symptom score that included nighttime symptoms when available. Second, we combined nasal symptom scores using the same methodology. Third, we created a nocturnal symptom score by combining symptoms experienced at night, such as awakening and sleep disturbance. We then combined a total medication score by combining maintenance and "as-needed" medications among studies reporting total medication use. As reported in some studies, we also generated a combined symptom and medication outcome score. The symptom scores were indexed on a 10-point scale. Peak expiratory flow (PEF) values were analyzed as reported using morning values in milliliters per minute. For statistical synthesis, we used both random-effects and fixed-effects models.19 The random-effects model assumes that there is a single true value underlying all the study results, and that the observed variability in results beyond what is attributable to within-study variability. The fixed-effects model assumes that there is only one true value underlying the study results, and the observed estimates of effect differ from each other only because of random error. The fixed-effects model only takes into account within-study variability.

Results

Study Selection

Our search strategies identified 10 randomized trials evaluating the effect of air filtration systems in patients with asthma.20–29 Four of 10 authors of the original studies responded to our request for further studies or additional information. Agreement on studies to be included was 100%.

Validity Assessment

The validity of included trials is summarized in Table 1. Eight of the 10 trials used a crossover design.20–26,29 Masking of treatment allocation (eg, concealment of treatment allocation prior to randomization) was not documented in any trial. After randomization, patients were blinded to whether their air filter was active or not in 9 of 10 studies.20–24,26–29 Blinding of health-care workers was conducted in two trials.24,29 Blinding of outcome assessors occurred in all 10 trials. Of the 216 total patients enrolled in these 10 studies, 26 patients were unavailable for follow-up. Intention-to-treat analysis was reported in two trials.25,27

Clinical Characteristics

Five of 10 trials enrolled exclusively adults,22,24,26–28 while 1 trial enrolled exclusively children29 (Table 2). The sample size ranged from 9 to 45 participants in each study, for a total of 216 patients across all studies.

Outcomes

Multiple outcome measures were used to determine the effectiveness of air filters in each study (Table 2). Five studies reported lung function,23,25–27,29 All but one study used a subjective measure of symptoms.27 However, none of these trials employed validated scales to measure clinical symptoms or quality of life. Five studies reported allergen levels.22,25–28

Air filtration systems were not associated with any differences in medication use or symptom/medication scores (Table 3). We found no improvement in morning PEF values whether the fixed- or random-effects model was used for data pooling (Fig 1).

Two trials showed that air filters were associated with significantly fewer symptoms.20,22 Two studies reported a statistically significant decrease in airway responsiveness associated with air filter exposure.23,29

We present the meta-analysis of study results in Table 3. There was a trend toward lower total symptom scores as shown by a weighted mean difference of 0.76 (95% confidence interval [CI], 2.17 to 0.65; p = 0.29) on a 10-point scale using the random-effects model. Using the fixed-effects model, there was no change in total symptom scores as shown by a weighted mean difference of 0.76 (95% CI, 2.17 to 0.65; p = 0.29) on a 10-point scale using the random-effects model.
model, the symptom improvement was statistically significant (weighted mean difference of 0.47; 95% CI, 0.69 to 0.25; \(p<0.01\)). However, the magnitude of this apparent benefit on symptoms differed across studies (\(p\) value for heterogeneity \(<0.01\)). These results are graphically depicted in Figure 2. The most conservative estimate of the effect of HEPA filters on symptoms is shown by the random-effects model and the associated wide CI. Air filters were not associated with any improvement in nasal symptoms. We also found a trend toward less sleep disturbance associated with air filters, as shown by a weighted mean difference of 1.08 (95% CI, 2.78 to 0.62; \(p=0.21\)) using a random-effects model, or 0.93 (95% CI, 1.44 to 0.42; \(p<0.01\)) using a fixed-effects model. However, these study results were also heterogeneous, weakening the inferences we can draw from this meta-analysis (\(p\) value for heterogeneity \(<0.01\)).

**Discussion**

In this systematic review of 10 randomized clinical trials among adults and children with asthma and allergy symptoms, we found a small but statistically significant difference in total symptoms and sleep.
disturbance associated with use of domestic air filters. We did not identify any benefit conferred by air filters with respect to nasal symptoms, medication use, or PEF values.

We adhered to rigorous systematic review methods and transparent reporting in this review. Jadad and colleagues previously summarized the clinical, methodologic, and reporting aspects of systematic reviews and meta-analyses on the treatment of asthma, highlighting how serious methodologic flaws limited their usefulness. Strengths of this systematic review include a focused clinical question, a comprehensive search for published and unpublished research, explicit selection criteria, validity assessments conducted in duplicate independently, and reporting of the heterogeneity of study results.

In critically appraising review articles, it is important to distinguish between the quality of the review methods and the quality of the studies included in the review. Accordingly, we evaluated and reported the randomized trial methodology in detail, thereby allowing readers to make their own inferences about the primary evidence. None of the studies explicitly reported on concealment of treatment allocation. Few studies reported strategies to maintain the blinding of participants, caregivers, clinicians, and outcome assessors; however, eight studies used sham air filters in the control period (Table 2).

Of the 10 randomized trials included in this systematic review, 9 trials evaluated asthma symptoms, but none included a validated generic or disease-specific quality-of-life instrument. At the time that many of these trials were conducted, few such instruments were available. Some simple symptom measures used in these trials may be insensitive to detect clinically important improvements due to environmental modifications. This hypothesis is supported by the observation that a reduction in airborne particulate matter associated with air filters did not always correlate with an improvement in symptoms. Currently available valid and reliable disease-specific quality-of-life or symptom tools in this field include the Asthma Quality of Life Questionnaire, the Living With Asthma Quality of Life Questionnaire, and the Asthma Control Questionnaire for adults, and the Pediatric Asthma Quality of Life Questionnaire for children.

The dearth of randomized trials evaluating the effect of air filters in children merits comment. Only one study enrolled exclusively children, despite the high and growing prevalence of asthma in this population.

Figure 2. Weighted mean difference for total symptoms. This figure shows the results of four randomized trials of domiciliary air filtration systems with respect to total asthma symptoms. Overall, a modest improvement in symptoms is shown by the pooled data. The fixed-effects analysis shows a significant reduction in symptoms, while the random-effects analysis shows a trend toward improvement.
population. The Seattle-King County Healthy Homes Project, which surveyed low-income urban caregivers of children with asthma, found that 12% used a vacuum with a HEPA quality filter. However, the random-effects model meta-analysis in this review that gives smaller studies proportionally greater weight in the pooled estimate, and results in more conservative interpretation of the effect of HEPA filters, suggests no overall benefit in terms of symptoms and sleep disturbance. These findings, and the fact that disease-specific outcomes were not measured, precludes making guidelines or policy recommendations about the use of air filters. However, the epidemiologic trend of increased asthma and allergy symptoms, the growing importance of patient empowerment through symptom control, and the need to measure outcomes that are important to patients suggest that further large rigorous randomized trials of environmental interventions such as air filters are warranted.

REFERENCES
17 Guyatt GH, Sackett DL, Cook DJ. Users’ guides to the medical literature: II. How to use an article about therapy or prevention; A. Are the results of the study valid? Evidence-Based Medicine Working Group. JAMA 1993; 270:2598–2601
31 Moher D, Cook DJ, Eastwood S, et al. Improving the quality of reports of meta-analyses of randomised controlled trials:
the QUORUM statement. Quality of Reporting of Meta-
analyses. Lancet 1999; 354:1896–1900
32 Jadad AR, Moher D, Browman GP, et al. Systematic reviews
and meta-analyses on treatment of asthma: critical evaluation.
BMJ 2000; 320:537–540
33 Juniper EF, Guyatt GH, Epstein RS, et al. Evaluation of
impairment of health related quality of life in asthma: devel-
opment of a questionnaire for use in clinical trials. Thorax
1992; 47:76–83
34 Juniper EF, Buist S, Cox FM, et al. Validation of a standard-
ized version of the Asthma Quality of Life Questionnaire.
Chest 1999; 115:1265–1270
35 van der Molen T, Postma DS, Schreurs AJM, et al. Discrim-
inative aspects of two generic and two asthma-specific instru-
ments: relation with symptoms, bronchodilator use and lung
function in patients in patients with mild asthma. Qual Life
36 Juniper EF, O’Byrne PM, Guyatt GH, et al. Development
and validation of a questionnaire to measure asthma control.
Eur Respir J 1999; 14:902–907
37 Juniper EF, Guyatt GH, Feneley DH, et al. Measuring quality
of life in children with asthma. Qual Life Res 1996; 5:35–46
environment of low-income urban children: preliminary find-
ings from the Seattle-King County Healthy Homes Project. J
Urban Health 2000; 77:50–67
39 Bero LA, Jadad AR. How consumers and policymaker use
systematic reviews for decision making. Ann Intern Med
1997; 127:37–42