

Clinical effects of air filters in homes of asthmatic adults sensitized and exposed to pet allergens

H. Francis, G. Fletcher, C. Anthony, C. Pickering, L. Oldham, E. Hadley, A. Custovic and R. Niven

North West Lung Research Centre, Wythenshawe Hospital, Manchester, UK

Summary

Background Despite medical advice, many pet-allergic asthma sufferers refuse to remove the pet to which they are sensitized from their home.

Objective We aimed to assess the clinical effects of air cleaners in the homes of adult asthma patients sensitized and exposed to cats and/or dogs.

Methods We performed a randomized, parallel-group study of 30 asthmatic adults sensitized to and sharing a home with cats or dogs. The effects of placing air cleaners in the living room and bedroom for 12 months and using high efficiency particulate air filter vacuum cleaners (active group) were compared with using these vacuum cleaners alone (control group). Measures of airway responsiveness, treatment requirement, lung function, peak flow, reservoir and airborne allergen were recorded before, during and after the interventions. A beneficial clinical response was assessed in terms of a 'combined asthma outcome'. This was defined as a two or more doubling dose improvement in bronchial hyper-reactivity to histamine and/or a reduction in treatment requirement of at least one step change on the British Thoracic Society guidelines for asthma treatment.

Results A beneficial clinical response was observed in 10/15 subjects in the active group compared with 3/15 in the control group after 12 months intervention ($P=0.01$). No significant differences between the active and control groups were detected for changes in measures of lung function, reservoir pet allergen and airborne pet allergen during the study.

Conclusion Whilst the study design has not allowed complete exclusion of a placebo effect, we believe that this pragmatic study of adult asthmatic patients sensitized and exposed to pets resulted in a small, but significant improvement in combined asthma outcome.

Keywords adults, air cleaner, allergen avoidance, allergens, asthma, bronchial hyper-responsiveness, HEPA, lung function, pets

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Introduction

Cats and dogs are the most popular pets in the western world and up to a third of asthma sufferers share their home with a pet [1]. Sensitization to cat allergen has been shown to be a risk factor for patients seeking treatment in emergency rooms [2]. Despite continued symptoms many cat- or dog-allergic patients consider removal of the animal to be an unacceptable option [3].

Airborne cat and dog allergen can be detected in undisturbed conditions for prolonged periods [4–7], whereas house dust mite allergen only becomes airborne after vigorous disturbance and settles rapidly [7–9]. Pet allergens are carried on smaller particles than house dust mite allergen [7]. This is likely to underlie

the rapid onset of symptoms experienced by cat- or dog-allergic patients entering a house with a pet [4, 6].

High-efficiency particulate air (HEPA) cleaners have been shown to effectively remove pet allergen from the air [5, 10, 11]; however, these devices were shown to be ineffective in improving asthma control in dust mite-sensitized individuals [10, 12]. HEPA vacuum cleaners have been shown to reduce reservoirs of pet allergen [13, 14], without leaking allergen [15].

Where removal of the pet is not an option, alternative methods of reducing allergen loads are necessary. Very few studies have assessed the clinical effects of avoidance measures in pet-allergic patients. A recent study investigating the use of air cleaners in the homes of children sensitized and exposed to pet allergen demonstrated improvements in bronchial hyper-reactivity [16]. However, a similar study of adults with asthma and/or allergic rhinitis did not detect any significant effect of air cleaners on clinical measures [17]. The aim of this study was to assess the effect of using air cleaners in addition to HEPA

Correspondence: Helen Francis, North West Lung Research Centre, Wythenshawe Hospital, Southmoor Road, Manchester M23 9LT, UK.
E-mail: hfrancis@fsl.with.man.ac.uk

vacuum cleaners over HEPA vacuum cleaners alone on combined asthma outcome.

Materials and methods

Adult subjects with asthma, between the ages of 18 and 65 years, were recruited from a chest clinic and through local advertising. A sample size of 30 completed subjects was set, based on an 80% power to detect a 20-mL change in morning or evening peak flow recording. To be included in the study, subjects were required to keep a cat or dog (against medical advice) and have a positive skin prick test (weal diameter of 3 mm or more after correction for the negative control value) to the relevant animal.

Approval for the study was obtained from South Manchester Local Research Ethics Committee and all subjects gave informed consent.

Study design

The design was a randomized, parallel group study with HEPA vacuum cleaners only as the control arm. Eligible individuals entered a run-in period lasting 6 weeks, during which time they were required to be on stable asthma treatment.

At the end of the run-in, measures of treatment requirement, lung function and bronchial hyper-reactivity were recorded and the subjects were randomized to either the active group, receiving Honeywell Envirocaire HEPA cleaners (model DA-5018, Honeywell Consumer Products Ltd, Hallesowen, UK) plus Dyson (model DC02, Dyson, Malmesbury, UK) HEPA vacuum cleaners or the control group, receiving HEPA vacuum cleaners alone. The air cleaners were placed in the living room and bedroom of the active subjects and instructions were given for the units to be left running continuously. All subjects were asked to vacuum their carpets using the HEPA vacuum cleaner a minimum of twice per week. The intervention period of the study lasted 12 months. At the end of the 12-month period, subjects again underwent lung function testing and assessment of bronchial hyper-reactivity and treatment requirement.

During the study peak flow diary data were recorded, reservoir dust samples were collected and air sampling was carried out at baseline (end of run-in period), 6 months and 12 months.

The primary endpoint of the study was termed 'combined asthma outcome' (defined by bronchial hyper-reactivity and treatment requirement). Additional endpoints were changes in lung function and allergen levels.

Assessment of combined asthma outcome

The primary endpoint of combined asthma outcome was assessed by bronchial (histamine) reactivity and treatment requirement. Bronchial hyper-reactivity to histamine was assessed using the method of Yan et al. [18], with the histamine being delivered via a dosimeter. Measurements of FEV₁ were made 60 s after dosing and the higher of the two measurements was recorded. When a dosing step required more than one inhalation, the inhalations were given in consecutive breaths. The test was stopped when the post-saline FEV₁ dropped by 20% or more, or a maximum PD₂₀ of 3.91 µmol histamine was reached.

Subjects' treatment was classified by the stage of the UK British Thoracic Society guidelines [19]. A pragmatic approach to asthma treatment was taken, with any changes in medication being left in the hands of the family practitioners (who were blind to the active/control nature of their patients in the study).

For the purpose of this study a beneficial clinical response (improvement in combined asthma outcome) was defined as at least one of:

- a two or more doubling dose improvement in histamine reactivity (representing at least a fourfold increase in the amount of histamine needed to achieve the same fall in FEV₁), or
- a reduction in treatment amounting to at least a one step change.

Measurement of lung function

Lung function was assessed by measuring FEV₁ and FVC using a dry bellows spirometer (Vitalograph Ltd, Maids Moreton, UK). Morning and evening peak flow diaries were recorded for 2-week periods at 6-monthly intervals during the study. Peak flow was measured using a mini-Wright peak flow meter (Clement Clarke International Ltd, Harlow, UK) and the best of three attempts was recorded. Diurnal variation and mean peak flow over each 2-week period were calculated.

Measurement of allergen levels

Air samples were collected in undisturbed conditions in the living room using a high volume air sampler (Rotheroe-Mitchell, London, UK) placed at 1 m above the floor for 1 h. Samples were processed and cat (Fel d 1) and dog (Can f 1) allergen content was determined using a two-site monoclonal antibody based ELISA as previously described [4, 5].

Reservoir dust samples were collected by vacuuming a 1-m² area of the living room and bedroom carpet for 2 min using a dust sampler (Medivac plc, Wilmslow, UK) and processed as described previously [20].

Data analysis

All statistical analyses were performed using the SPSS package (SPSS Inc., Chicago, IL, USA). Improvement in combined asthma outcome was compared using χ^2 test. Lung function data were converted to percentage of predicted values. The percentage change from baseline values was calculated and the differences between case and control groups were calculated using the Student *t*-test. Allergen data were found to follow a log-normal distribution, therefore geometric means were calculated for each time-point. These were then converted to percentage changes from baseline. Changes in allergen levels between the cases and controls across the study were compared using analysis of variance (ANOVA) with repeated measures. Statistical significance was set at the conventional < 5% level.

Results

Thirty-two patients were recruited and 30 subjects completed the study. Two subjects were withdrawn during run-in due to failure to comply with the protocol. Fifteen subjects were randomized to the active group and 15 subjects were randomized to the control group. Demographic and clinical characteristics of

the study population are presented in Table 1. There were no significant differences between the active and control groups for any demographic or clinical variable.

Effects on clinical parameters

Combined asthma outcome Combined asthma outcome, as determined by histamine reactivity or treatment requirement, was found to improve during the study period in the active compared with the control group, as shown in Table 2. Two subjects in the active group were able to withdraw their preventative medication without any relapse in symptoms and one individual no longer needed their asthma medication (baseline medication was short acting B₂ agonist only).

Data for both time-points were available for 24 of the subjects: one individual was contraindicated due to poor lung function, two became pregnant and three were not well enough to perform the challenge test. Asthma treatment data were available for all 30 subjects.

The compliance of the active subjects with the air cleaners was monitored using timer clocks within the units. A total proportion of actual running time to available time was calculated.

This assessment demonstrated that the units were left running for longer in the active subjects with improved combined asthma outcome (mean running time 81.4%) compared with those that had no improvement in combined asthma outcome (mean running time 60.3%).

Lung function Spirometry and peak flow data are presented in Table 3. Changes in lung function during the study period were not significantly different in active compared with control subjects, in terms of FEV₁, FVC, mean peak flow or diurnal variation in peak flow.

Allergen levels Airborne and reservoir levels of Fel d 1 and Can f 1 are presented in Table 4. Baseline levels of airborne and reservoir allergen were higher in control homes compared with those of the active group. However, these differences were not statistically significant and hence were unlikely to confound the results.

Airborne allergen levels reduced in active and control houses during the study period. This reduction was statistically significant for Can f 1 within the active ($P < 0.01$) and control group ($P < 0.03$). However, there was no significant difference

Table 1. Clinical and demographic characteristics of study population

	Active (n = 15)	Control (n = 15)	Total (n = 30)
Male	5	2	7
Female	10	13	23
Age (yr), mean (95% CI)	36.8 (29.3–44.3)	41.6 (34.4–48.9)	39.1 (34.1–44.1)
Current smoker	1	3	4
Inhaled steroids	12	15	27
Atopic to cat	14	15	29
Atopic to dog	14	15	29
Atopic to <i>Alternaria</i>	12	13	25
Atopic to house dust mite	15	15	30
Atopic to grass pollen	15	15	30
FEV ₁ % predicted, mean (95% CI)	87.3 (80.3–94.2)	88.8 (76.8–100.8)	88.0 (81.7–94.4)
PD ₂₀ histamine, μ mol, GM (95% CI)	0.19 (0.07–0.56)	0.23 (0.08–0.68)	0.21 (0.10–0.43)

CI = confidence interval; GM = geometric mean.

Table 2. Number of subjects with improvements in combined asthma outcome

	Active group	Control group	P
Improvement in combined asthma outcome	10/15	3/15	0.01
Improvement in histamine reactivity	7/13	3/11	
Reduction in treatment requirement	3/15	0/15	

Table 3. Lung function by month of study and study group. Data are presented as means and standard deviations

	Active group			Control group		
	0 months	6 months	12 months	0 months	6 months	12 months
FEV ₁ (L)	2.79 $\pm$ 0.87	–	2.84 $\pm$ 0.87	2.62 $\pm$ 0.80	–	2.59 $\pm$ 0.89
FVC (L)	3.67 $\pm$ 1.00	–	3.71 $\pm$ 0.96	3.58 $\pm$ 0.91	–	3.52 $\pm$ 0.95
Mean peak flow (L/min)	377 $\pm$ 95	380 $\pm$ 94	390 $\pm$ 130	373 $\pm$ 111	385 $\pm$ 83	404 $\pm$ 109
DV (%)	0.76 $\pm$ 8.12	0.98 $\pm$ 3.84	1.22 $\pm$ 6.93	0.75 $\pm$ 6.69	1.17 $\pm$ 5.02	0.15 $\pm$ 2.31

DV = diurnal variation in peak flow.

Table 4. Allergen levels by month of study and study group. Data are presented as geometric means and standard deviations

	Active group			Control group		
	0 months	6 months	12 months	0 months	6 months	12 months
Airborne Can f 1 ($\mu\text{g}/\text{m}^3$)	22.1 $\pm$ 2.6	10.7 $\pm$ 4.5	2.8 $\pm$ 3.7*	40.1 $\pm$ 1.4	19.9 $\pm$ 4.0	3.69 $\pm$ 5.4*
Airborne Fel d 1 ($\mu\text{g}/\text{m}^3$)	8.7 $\pm$ 4.6	4.7 $\pm$ 5.7	3.1 $\pm$ 3.4	15.0 $\pm$ 3.9	6.9 $\pm$ 2.0	6.7 $\pm$ 3.0
Bedroom carpet Can f 1 ($\mu\text{g}/\text{g}$)	8.6 $\pm$ 3.4	7.7 $\pm$ 10.7	20.2 $\pm$ 15.5	39.7 $\pm$ 4.1	26.6 $\pm$ 6.2	134.1 $\pm$ 18.5
Living room carpet Can f 1 ($\mu\text{g}/\text{g}$)	198.2 $\pm$ 3.0	178.8 $\pm$ 4.0	145.2 $\pm$ 3.3	494.1 $\pm$ 2.3	133.8 $\pm$ 4.1	317.5 $\pm$ 7.5
Bedroom carpet Fel d 1 ($\mu\text{g}/\text{g}$)	73.8 $\pm$ 5.9	78.5 $\pm$ 11.7	13.2 $\pm$ 21.5	77.1 $\pm$ 8.5	78.8 $\pm$ 14.8	82.1 $\pm$ 9.2
Living room carpet Fel d 1 ($\mu\text{g}/\text{g}$)	156.7 $\pm$ 6.3	159.8 $\pm$ 7.2	92.0 $\pm$ 3.4	207.0 $\pm$ 9.6	185.9 $\pm$ 5.2	52.0 $\pm$ 18.7

* indicates a statistically significant change in allergen level within the group at 12 months compared with baseline.

between the two groups in the changes in airborne allergen levels across the study period.

Twenty-eight of the houses were carpeted throughout. Reservoir samples were not analysed for one subject due to a change in flooring material during the study. One subject had hard-wood flooring from which samples of reservoir dust were collected and analysed. Reservoir animal allergen levels did not change significantly at 12 months compared with baseline levels within the active or control group. Furthermore, there was no significant difference between the active and control groups in the changes in reservoir animal allergen measured across the study.

Discussion

There are few studies that have assessed the use of air cleaners for reducing pet allergens, and even less information is available regarding the clinical effects of this intervention. Although subject to small differences in smoking, asthma medication and type of pet owned, this study was able to detect a significant benefit of the use of air cleaners on combined asthma outcome in adults. There was evidence for a trend for increased use of air cleaners in those active subjects that had improvements in combined asthma outcome.

A study of adults with asthma and/or allergic rhinitis who were both sensitized to cat allergen and sharing a house with a cat demonstrated significant reductions in Fel d 1 after the use of HEPA cleaners for 3 months, but no effect on clinical measures [17]. However, the air cleaners were placed in the bedroom only. A more recent study by van der Heide, also with a 3-month intervention period, demonstrated that the use of air cleaners was associated with an improvement in airway hyper-responsiveness compared with baseline values [16], but had no effect on lung function or reservoir allergen levels. The latter study involved asthmatic children rather than pet-allergic adults and incorporated the placement of air cleaners in both the bedroom and living room. In this study, the introduction of air cleaners in addition to HEPA vacuum cleaners to the homes of pet-allergic asthmatics was found to confer a statistically significant improvement in combined asthma outcome over HEPA vacuum cleaners alone. Similarly to the Van der Heide study, air cleaners were placed in the living room and bedroom. The use of air cleaners in both living rooms and bedrooms may therefore be more effective than their use in bedrooms alone. This may be because, in contrast to house dust mite where the

highest levels are detected in the mattress, the most significant exposure to pet allergen may be the living room. This study and past work [5] has detected lower levels of pet allergen in bedrooms compared with living rooms within British homes.

Reservoir levels of pet allergen were not found to reduce significantly during the study. Although the concentration of animal allergen within reservoir dust (including mattresses, upholstery and carpets) has been used as a proxy measure of individuals' allergen exposure, the accuracy of this has been questioned [21].

The discrepancy between the observed improvement in combined asthma outcome with the use of air cleaners and the failure to detect a reduction in airborne allergen levels in active compared with control subjects may be due to a lack of appropriateness of the currently used allergen sampling tools.

Previous work has assessed the short-term effect of running HEPA cleaners on airborne cat allergen [5]. This study involved measuring airborne pet allergen for three separate 1 h sampling times at 4-h intervals on two consecutive days. On day one a HEPA cleaner was running for 8 h (and was started after the first hour air sample was collected) and on day two the air cleaner was switched off. A more than fivefold reduction in airborne Fel d 1 was observed on day one (with the HEPA cleaner running), but Fel d 1 levels dropped (approximately a twofold reduction) even on day two when the air cleaner was not in use. The author postulated that this may be due to the effect of the air sampling: the air sampler draws 1/6 of the total volume of air within the room through a 0.3- μm filter every hour, effectively 'cleaning' the air it samples. A similar phenomenon was observed when testing the effect of HEPA cleaners on airborne dog allergen [11]. The air sampling method used in this study may therefore have confounded the results. It may be useful to explore other methods of airborne sampling in future work.

Measurement of airborne allergen levels may also be dependent on the presence of animals, or the number of animals within the room at the time of sampling and may not be representative of personal exposure. Previous studies have documented significantly higher levels of airborne Fel d 1 [5] and Can f 1 [11] within a room when an animal was present compared with when the animal was elsewhere in the house. Differences in animal occupancy within the rooms sampled at different visits may have partly influenced the levels of airborne allergen detected. It was not practically possible to standardize the presence or absence of specific animals at the time of sampling in a real life study.

Alternatively, the reduction in airborne allergen observed in both cases and controls may be attributable to the use of the HEPA vacuum cleaners. In order to answer this, an additional control arm would have been necessary, comprising subjects who were randomized to no intervention or to ordinary (non-HEPA) vacuum cleaners. This was not incorporated into the study, as the assessment of the effect of HEPA vacuum cleaners on allergen levels was not one of the aims of this study.

The limitation of using HEPA vacuum cleaners as the only control group (i.e. not having a sham air cleaner control group) is that we are unable to completely exclude the possibility of a placebo effect occurring. Due consideration was given to issuing sham air cleaners to the control group. However, it was felt that patients left with a technical device for a year would be likely to give in to their natural curiosity during this period and become unblinded. A previous study we have performed with air cleaners supported this view (unpublished data). Furthermore, there is a possibility that running sham air cleaners (i.e. with no HEPA filter) could increase airborne allergen exposure in the control group due to disturbance caused by increased air flow rates over the flooring material. Such an increase in exposure in the control group may result in a worsening of asthma symptoms in this group (rather than providing a positive benefit in the active group).

In conclusion, although this study did not detect a significant effect of air cleaners plus HEPA vacuum cleaners over the use of HEPA vacuum cleaners alone on changes in reservoir or airborne allergen, a beneficial clinical response in terms of improvement in combined asthma outcome was demonstrated. Air cleaners may be of benefit in the management of animal-allergic asthmatic patients who refuse to part with their pets.

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