

Air filtration units in homes with cats: can they reduce personal exposure to cat allergen?

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Summary

Background Domestic air filtration units have previously been shown to cause a dramatic fall in airborne pet allergen levels in homes with pets. Clinical trials of air filtration units, however, have failed to reveal a significant beneficial effect. Personal pet allergen exposure during air filtration unit use has never been measured.

Objective To determine the effect of air filtration on inhaled cat allergen exposure in homes with cats.

Methods Nasal air samplers were worn to measure personal cat allergen exposure. The study was carried out in five homes with cats on 4 separate days examining four experimental conditions (cat absent or present, air filtration off or on). The two operators collected four baseline samples and two 15-min samples/h over three consecutive hours. Cat allergen-bearing particles were detected by immunoblotting and allergen concentrations measured by amplified enzyme-linked immunosorbent assay (ELISA).

Results There was a significant reduction in the quantity of the inhaled Fel d 1 when the air cleaner was used with the cat in the room. Fel d 1 halo counts (detransformed means) were 29.3 at baseline, 11.8 after 1 h, 10.0 after 2 h and 14.1 after 3 h, with no change on control days ($P = 1.00$). With the cat elsewhere in the house, a marginal, but statistically significant reduction was observed only after 3 h with the use of air cleaner (Fel d 1 halo count: baseline 12.4; 3 h 5.5; $P = 0.01$).

Conclusions The use of air filtration units appears to result in a much smaller reduction of inhaled cat allergen exposure than suggested by previous studies using standard air samplers. Cat removal remains the best advice to cat-allergic patients who experience symptoms upon exposure.

Keywords air filtration, cat allergen, environmental control, Fel d 1, nasal sampling

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Introduction

Many cat- or dog-sensitized asthmatic patients choose not to part with their pet. Environmental control with the pet *in situ* relies on several strategies (air filtration, replacement of carpets with hardwood floors and washing the pet). Air filtration units incorporate a coarse charcoal pre-filter for the collection of large particles and the elimination of odours, and a high efficiency particulate arrest (HEPA) filter which captures > 99.5% of particles < 0.3 μm in size – including the majority of aero-allergen-bearing particles. However, clinical trials of these units have failed to show a significant therapeutic effect [1, 2], despite one of these trials [1] reporting a near half reduction in ambient air cat allergen concentration. Other studies have suggested that domestic air filtration units reduce ambient pet allergen levels in homes by up to 90% [3, 4]. This discrepancy between apparent allergen reduction and therapeutic effect may be due to fundamental limitations in the methods used to quantify the amount

of allergen inhaled by individual patients. Ideally, measurement of allergen exposure should quantify allergen impacting on the respiratory mucosa and eliciting an immunological response. Most studies examining airborne pet allergen levels use standard air samplers, which sample allergen from ambient air and are driven by a vacuum pump at a fixed flow rate. Such samplers may not reflect personal allergen exposure directly inhaled by the individual. Recently, nasal air samplers (NAS) [5–7] have been developed. These are worn in both nostrils, naturally inspired particles impact onto an adhesive tape and allergen can be quantified by using an immunoblotting technique. Because the samplers collect particles as they are inspired through the nose, measurements with this device may therefore be more representative of the allergen load impacting on the respiratory mucosa. In bench tests [8], the samplers collect > 95% of particles 12 μm in diameter. Given that around 50% of airborne Fel d 1 is present on particles > 10 μm [3], particles collected by this device are clearly in the same size range as those on which Fel d 1 is airborne. The HEPA air cleaner removes particles some 10–100 times smaller than Fel d 1-bearing particles; therefore changes in Fel d 1 concentration occurring as a result of air filtration should be reflected in changes in particle number measured by the NAS. We aimed to investigate the

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effect of air filtration units in homes with cats on personal inhaled cat allergen (Fel d 1) exposure measured by NAS.

Methods

Study design

The study was carried out in five homes with cats, using a Honeywell air cleaner (model DA-5018E, Honeywell, Arlington Business Park, Bracknell, UK) with a clean air delivery rate of 221 m³/h. Four separate experimental conditions were examined on four separate days in the living room of each house: (i) cat in the room, air filtration unit switched on (active day); (ii) cat in the room, air filtration unit switched off (control day); (iii) cat elsewhere in the house, air filtration unit switched on (active day); (iv) cat elsewhere in the house, air filtration unit switched off (control day).

The median room size was 54.2 m³ (range 24.6–78.3 m³). On arrival, all doors and windows were shut. On the days when the sampling was carried out with the pet inside, cats were allowed to move freely throughout the room. On days when sampling was carried out with the pet outside, the pet was excluded from the room at least 60 min before starting the study. The same two investigators carried out all the nasal sampling, providing pairs of samples for each time point. Samples were collected by each investigator for processing by both the HALOgen technique and by an amplified enzyme-linked immunosorbent assay (ELISA) for Fel d 1.

The study consisted of a 1-h baseline period and a 3-h 'filtration period'. During the baseline period, each investigator took four consecutive 15 minute samples. Two of these samples were processed by HALOgen and two by ELISA. During a 3-h 'filtration period' both investigators took two 15-min samples: each hour at 15 min (for HALOgen) and 45 min (for ELISA) past the hour. Investigators remained sedentary throughout.

HALOgen assay

HALOgen kits (Inhalex Pty, Sydney, Australia) for the cat allergen Fel d 1 were used. The pairs of adhesive tapes from nasal air samplers were laminated onto a protein-binding membrane and immunostained for the cat allergen Fel d 1 [7]. Samples were coded and thus read 'blind'. Allergen-bearing particles appeared as a 'halo' of colour surrounding an inspired particle and were counted by light microscopy ($\times 40$) by two observers.

Amplified ELISA for Fel d 1

Pairs of nasal sampler adhesive tapes were placed in microcentrifuge tubes containing 1 mL 3% bovine serum albumin/borate-buffered saline/Tween-20 0.05%. Tubes were rotated for 2 h at room temperature (20 °C). Samples were then spun and eluates recovered and stored at –20 °C. Fel d 1 concentration was determined by ELISA [9] performed in conjunction with the Ampli-Q kit (Dako, Diagnostics Ltd, Denmark House, Ely, UK). The lower limit of detection was 0.4 ng/mL (0.1 mU/mL).

Statistical analysis

Counts from the left and right nostrils were summed. The intraclass correlation coefficient for triplicate counts taken from the investigator was 0.99. The interobserver 95% limits

of agreement [10] were –15.52 and +22.66. Using counts from either investigator made no difference to the final statistical interpretation. Count data were normalized by square root transformation [11]. They satisfied Mauchly's test of sphericity and are presented as square root detransformed mean and range. Data were analysed by analysis of variance (ANOVA) for repeated measures (SPSS v9.0, SPSS Inc., Chicago, IL, USA). This method is identical to the statistical method used in previous studies [3, 4]. The following were within-subject variables: time elapsed since completion of baseline samples, presence or absence of cat, status of air filtration unit (on/off), individual performing the sampling. A type I sums of squares custom model was used. Differences in levels were analysed by 'simple' and 'repeated' contrast options in SPSS. The conservative Greenhouse–Geisser significance values are quoted.

Results

Halo counts

The halo count data for four separate experimental conditions are presented in Fig. 1 and Table 1. There was a significant reduction in the quantity of the inhaled Fel d 1 when the air cleaner was used with the cat in the room ($P < 0.01$). Fel d 1 halo counts (detransformed means) were 29.3 at baseline, 11.8 after 1 h, 10.0 after 2 h and 14.1 after 3 h. There was no significant change in halo count on the control day ($P = 0.7$). With the cat elsewhere in the house, a marginal reduction was observed only after 3 h with the use of air cleaner (Fel d 1 halo count: baseline 12.4; 3 h 5.5; $P = 0.18$).

The following factors had a significant and independent effect on the halo count: (i) the use of the air filtration unit ($F = 7.69$, d.f. = 1, 4, $P = 0.05$); (ii) the effect of time ($F = 5.52$, d.f. = 2, 6, $P = 0.01$); (iii) the presence of the cat in the room ($F = 9.16$, d.f. = 1, 4, $P = 0.04$).

The selection of the operator wearing the nasal air sampler did not have a significant effect on the halo counts ($F = 1.37$, d.f. = 1, 4, $P = 0.31$).

Amplified ELISA

All samples were assayed on the same day. The mean coefficients of variation across the three plates were 14.0%, 19.8% and 30.7%.

The majority (94.5%) of ELISA measurements were below the limits of detection. Eleven samples had detectable allergen (median 0.74 ng/mL, range 0.59–3.77 ng/mL). Of the 11 samples with detectable allergen, nine were either from baseline samples or from days when the air filtration unit was switched off. Eight of 11 were from days when the cat was present.

Discussion

Previous studies of air filtration have only employed standard air samplers to measure airborne allergen levels. This is not because standard air sampling is a 'gold standard', but because until recently sensitive tools for personal air sampling were not available; lapel-mounted personal samplers are still driven by external fixed-rate pumps and not by respiration. Standard air samplers provide only surrogate measures for exposure (they

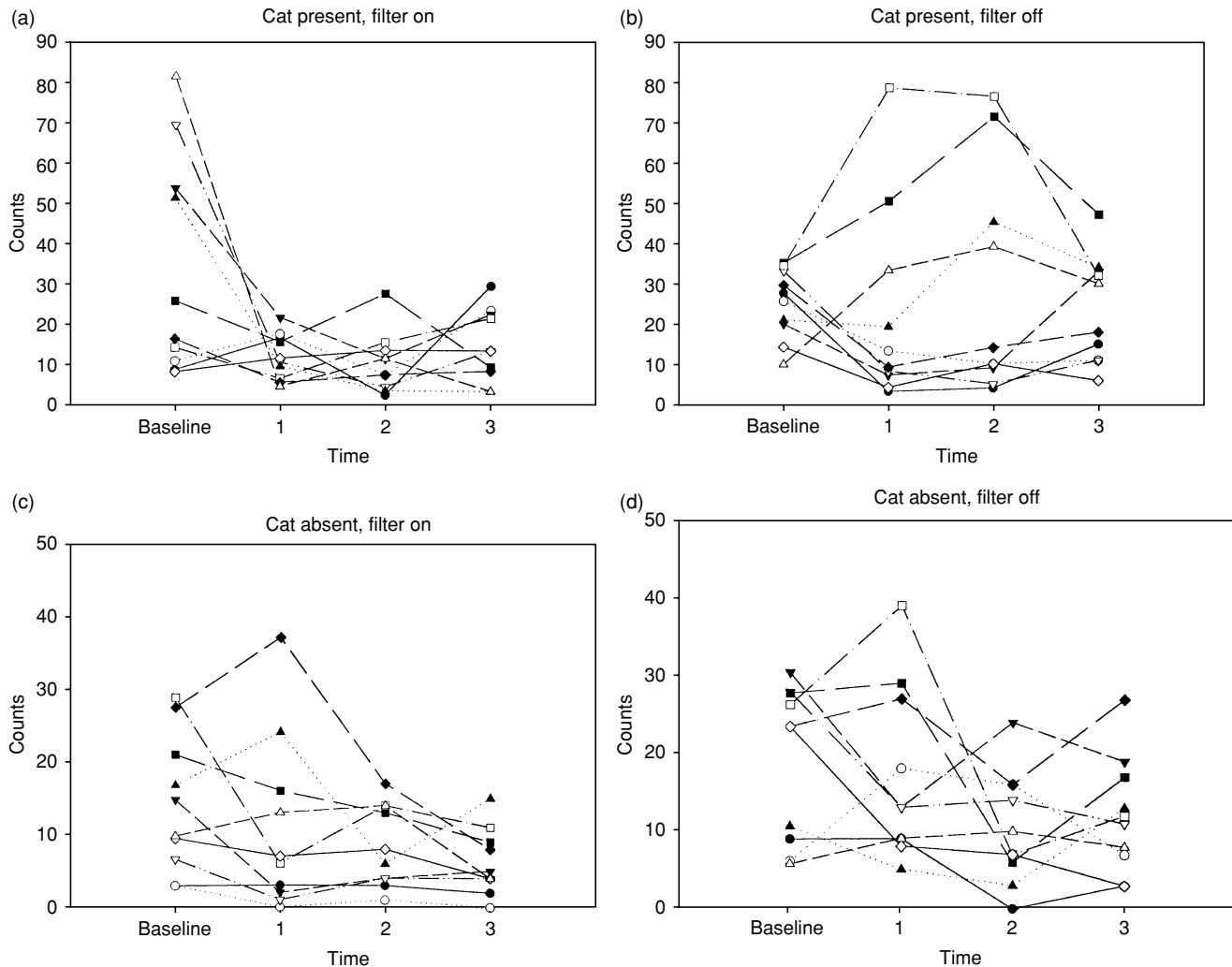


Fig. 1. Personal Fel d 1 exposure: (a) Cat present, active day; (b) Cat present, control day; (c) Cat absent, active day; (d) Cat absent, control day. Each measurement is represented by one data point.

Table 1. Summary statistics for Halo counts

Time	Cat present		Cat not present	
	Active <i>n</i> = 10	Control <i>n</i> = 10	Active <i>n</i> = 10	Control <i>n</i> = 10
Baseline	29.3 (6–104)	25.0 (11–57)	12.4 (4–35)	17.5 (3–40)
1 h	11.8 (5–22)	18.8 (4–79)	8.1 (0–37)	15.5 (5–39)
2 h	10.0 (3–28)	23.7 (5–77)	7.6 (1–17)	9.0 (0–24)
3 h	14.1 (4–30)	23.0 (7–48)	5.5 (0–8)	10.9 (3–27)
<i>P</i> -value	0.01	0.70	0.18	0.38

Values are square root detransformed means (minimum–maximum). Data are from five homes with two individuals sampling (*n* = 10).

cannot measure allergen directly impinging on the respiratory mucosa). Nasal air samplers too may only provide a surrogate for exposure, as they collect a certain size fraction of particles

entering the nose (and not the lung). Conceptually, however, they collect particles at least entering the human body at some point. Given that there is a discrepancy between the lack of observed clinical effect of air filtration units and their effect on allergen clearance, we felt it was important to conduct this study using a different tool altogether from the standard air samplers used in previous studies. An experimental comparison of standard air sampling and NAS is desirable, although the problems of one technique confounding the other and the inherent variability in aeroallergen concentrations are major obstacles to designing such studies. We therefore attempt to explain the differences between our results and those from other studies, bearing in mind that strict methodological comparisons are not possible.

The reduction in personal cat allergen exposure with air filtration was considerably lower than the 90% reduction observed in previous studies using standard air samplers [3, 4]. There was a fall in personal Fel d 1 exposure under all conditions (i.e. even when the air filtration unit was switched off). Furthermore, the effect of air filtration appeared small and only just reaches statistical significance.

Two previous studies evaluating domestic air filtration in homes with cats [3] and dogs [4] which used standard air samplers demonstrated that even on control days, pet allergen levels fall by up to 50% within the first 4 h of sampling. Two possible reasons for this are the use of standard air samplers to measure airborne Fel d 1 concentrations and natural dust settling. Standard air samplers run at high flow rates to increase the sensitivity of detection. This in itself may cause a downward trend in airborne allergen levels by extracting airborne allergen. However, the magnitude of allergen reduction on control days in studies using air samplers was similar to our data [3, 4], implying that this particular confounding factor cannot explain the discrepancy in the effect of air filtration units between the current and previous studies. Natural dust settling may contribute to the observed reduction in airborne allergen level and may even be exaggerated by the use of the nasal air sampler which preferentially collects larger particles ($> 10 \mu\text{m}$). However, such an effect would be expected to be similar on both active and control days and should not affect the assessment of the air filtration units.

Standard air samplers are placed in a fixed position in the room, whereas individuals wearing personal nasal air samplers are closer to the soft-furnishing allergen reservoirs such as the sofa. These reservoirs are likely to act as a constant source of exposure even for relatively sedentary participants. We speculate, therefore, that the magnitude of the reduction in airborne cat allergen with air filtration observed in other studies may therefore have been overestimated.

We observed that when the cat is present and the air filtration unit switched on, airborne Fel d 1 concentrations fell only modestly: after 3 h, the levels were similar to those before air filtration when the cat is elsewhere in the house. This may not be surprising, as Avner et al. [12] estimated that cats shed around 0.002%/h of their total Fel d 1 allergen load, or 230–2000 ng/h. De Blay [13] evaluated the effects of air exchange rate, cat presence, cat washing, carpet removal and air filtration on airborne Fel d 1 concentrations in an experimental room. The air filtration unit was most effective when the cat was not present, when there was no carpet in the room and if the floor was cleaned before switching the unit on. Could our data explain the lack of clinical benefit seen in clinical trials of HEPA air cleaners? Wood et al. [1] conducted a placebo-controlled study of air filtration in homes with cats over a 3-month period. An approximate reduction of only 50% in airborne Fel d 1 was measured, using a low-flow stationary air sampler. No clinical benefit was observed. Van der Heide et al. [2] performed a 6-month double-blind placebo-controlled study of air filtration in the living rooms and lounges in 20 children (all of whom were mite as well as cat- or dog-sensitized) and demonstrated an improvement in only a few clinical parameters (PC_{20} to adenosine monophosphate, peak flow variability). Airborne exposure to pet allergens was not recorded. There are several possible reasons why the observed clinical effects in these trials were so small; a genuine significant effect may be missed if merely subjective measures of severity are used, or if the study population has relatively good baseline scores for objective measures such as peak expiratory flow rate. Furthermore, where allergen reduction with the cat *in situ* is attempted, it may be feasible to attempt to reduce allergen in one room in the house from which the cat is excluded (such as the bedroom [1], or bedroom and living room [2]). However, transfer of allergen from reservoirs

in other parts of the house (e.g. carpets [3], walls [14] and clothing [15]) may offset potential improvements due to allergen reduction in the rooms with air cleaners. It is likely that HEPA air filtration units fail to remove enough cat allergen in the presence of an ever-renewable supply. Our data are conducive with the hypothesis that air cleaning reduces personal cat allergen exposure by less than has previously been estimated, and this level of reduction in personal exposure is insufficient to confer the clinical benefit.

We were able to detect airborne cat allergen by amplified ELISA mainly when the cat was present or the air filtration unit was switched off. This should be borne in mind when designing future studies where personal allergen exposure is being measured by NAS. The HALOgen method appears to be a more sensitive tool for the measurement of inhaled allergen load.

In conclusion, the use of air filtration units results in a smaller reduction of inhaled cat allergen exposure than that suggested by previous studies using standard air samplers. Cat removal remains the best allergen avoidance advice to cat-allergic patients who experience symptoms upon exposure.

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