

Use of an Electrostatic Dust Cloth for Self-Administered Home Allergen Collection

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Most epidemiologic studies employ a vacuum cleaner used by a trained technician to collect household allergens. This approach is labor intensive, equipment dependent, and impractical if study subjects reside over a wide geographic area. We examined the feasibility of a self-administered dust collection method, using an electrostatic cloth sent by conventional mail, to obtain allergen measurements. Thirty-two nonasthmatic twins from the California Twin Program wiped areas in the family room, kitchen, and bedroom, according to standardized instructions, and returned the cloths by mail. Allergen concentrations for Der-p-1, Der-f-1, Fel-d-1, and Bla-g-2 were determined using ELISA, and intrahouse and room-to-room concentrations were compared. Der-p-1 and Fel-d-1 were found in most homes, with highest concentrations in bedrooms and kitchens, respectively. Der-f-1 and Bla-g-2 were rarely found. Intrahouse Der-p-1 and Fel-d-1 concentrations were highly correlated and statistically significant (for Der-p-1, bedroom vs. kitchen, $p = .0003$, bedroom vs. family room, $p = .0001$, and family room vs. kitchen, $p = .002$; for Fel-d-1, bedroom vs. kitchen, $p = .0004$, bedroom vs. family room, $p < .0001$, and family room vs. kitchen, $p = .0001$). Reported cat ownership was strongly correlated with household Fel-d-1 concentrations ($p < .005$). In another comparison from different homes of children enrolled in the La Casa atopy prevention study, allergen concentrations measured from dust collected by a single operator from the left and right half of the same room in 21 homes were compared. Levels of Bla-g-2, Der-p-1, and Fel-d-1 concentrations collected from right and left halves of the same room were highly correlated, with r^2 ranging from .7 to .9, and were highly statistically significant (all p values $< .01$). We conclude that nonintrusive and self-administered dust collection, using commercially available electrostatic dust cloths, sent by conventional mail services, is a promising alternative to technician-collected vacuumed dust for measuring indoor allergens in population-based studies, although further validation of the method is necessary.

Indoor allergens have been identified as asthma triggers and have been implicated in the etiology of asthma and allergy (Platts-Mills et al., 1997). Allergen measurements for most epidemiologic studies are made from dust collected by a trained technician using a vacuum cleaner insert (Eggleston et al., 1998; Peat et al., 1997). Understanding of the role of indoor exposures in allergic disease has been limited by the expense and intrusiveness of this method. For valid intrahouse comparisons, the vacuum cleaner approach requires that the same model of vacuum cleaner is used, and that the collection is administered by a trained technician, so that differences in sampling are minimized (Eggleston et al., 1998; Peat et al., 1997). This is often impractical when residences cover a wide geographic area.

Prior to this study, we developed a population-based registry of adult California-born twins in order to study tobacco-related diseases in twins (Cockburn et al., 2001). In that study, we received self-administered questionnaires from at least one member of 34,890 twin pairs, of which 5716 reported asthma in at least one member of the pair. These twins are a highly motivated and compliant population and ideal for a large-scale studies, but it has not been possible to evaluate indoor allergen exposure due to long distances between subjects' residences. To utilize this highly compliant population for studies, successful exposure sampling strategies should be easy to administer. We examined the feasibility of using an electrostatic dust cloth, returned by conventional mail, to collect household dust samples for allergen measurements, in order to evaluate the method for future studies of allergy and asthma in the twin cohort.

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Methods

The study was approved by the University of Southern California Institutional Review Board in compliance with federal regulations.

A dust cloth marketed by Procter and Gamble Company (brand name 'Swiffer'), was chosen as the collection device since it is electrostatic, inexpensive, easy to obtain, and effective at collecting dust (Sercombe et al., 2002). We developed a standardized protocol for dust collection from the kitchen, family or common use room, and bedroom (preferably that of a child between 3 and 12 years of age). Subjects were instructed to wipe in specific areas of each room (i.e., floor molding, all open shelves, closet shelves and molding, behind the refrigerator, tops of picture frames and clocks), in addition to standard areas such as mattresses and floors, to obtain representative samples of long-term house dust. Subjects were told to complete the collection within 15 to 30 minutes.

In a pilot study of five homes, we confirmed that the allergens of interest could be detected from the dust cloth sampling approach.

We then identified healthy nonasthmatic twins from the population-based registry of California-born twins over 21 years old (Cockburn et al., 2001) who had participated in a study of smoking and cytokines (Cozen et al., 2004). Twins were not randomly selected — we mailed out wipe test kits and letters explaining the study in batches to twins who had just completed participation in a lengthy study which involved traveling to laboratories, getting a blood specimen drawn, and shipping it to us the previous year (Cozen et al., 2004). As we were not testing compliance in this demonstration project, no follow up was performed, and we ended the mailing when our goal of 30 kits was reached (e.g., 32 kits were received by the end of the study).

We mailed packages containing electrostatic cloths (Swiffers) in three separate plastic bags (one for each room), along with specific instructions and prepaid return mailers. We enclosed a fourth dust cloth as a blank quality control, to remain unopened in the plastic bag, as well as a brief questionnaire to obtain information on pet ownership and evidence of cockroaches.

From collected dust, we measured four common household allergens implicated in asthma etiology or exacerbation: *Dermatophagoides pteronyssinus* (Der-p-1), *Dermatophagoides farinae* (Der-f-1), *Felis domesticus* (cat dander; Fel-d-1), and *Blattella germanica* (cockroach; Bla-g-2; Platts-Mills et al., 1997).

In order to assess the correlation with a standard method of dust collection, additional collections were performed by trained technicians in 21 randomly selected homes of children participating in the La Casa asthma intervention study (prior to intervention). A description of the study can be found elsewhere (McConnell et al., 2005). For this follow-up, a technician visited the home and performed the following

comparison: the kitchen and child's bedroom were divided in half, and each half of the room was wiped using the same type of electrostatic dust cloths sent out to the twins. The right and left half of each room were compared for allergy concentration as described below.

Laboratory Methods

Electrostatic cloths were soaked in a buffer solution of PBS for 2 hours at 37° C in a rocking water bath to remove all dust particles from the cloth. The solution was then centrifuged at 100 g for 5 minutes to eliminate any large sediments. The supernatants were then assayed for allergen concentrations by ELISA using commercially available paired antibodies and standards (Indoor Biotechnologies, Charlottesville, VA).

Dust mites (Der-p-1 and Der-f-1), cat dander (Fel-d-1), and cockroach (Bla-g-2), were all assayed according to manufacturer's recommendations. Optical density readings were converted to concentrations according to the slope of the standard concentrations. Measurements were standardized by weight of dust, by subtracting the mean weight of unused Swiffers from the weight of each individual used Swiffer, and expressed as $\mu\text{g/g}$ dust. Since the weight did not vary appreciably, and since weighing each wipe before sending it would have added a great deal of effort, we used the mean weight as calculated from weighing a sample of 50 unused Swiffers (mean weight = 8.07 g; SD of 0.11 g; cv = 1.36%). A second standardization was done by protein concentration. Protein determination was performed using a modified Lowry test on the supernatants and values expressed as $\mu\text{g/g}$ (per ml) of protein.

To ensure that the process was efficient for extracting particles and antigen, we spiked five blank filters with known amounts of house dust mite allergen and the extraction process was performed as described. For all five filters the antigen recovery rate was greater than 95%, probably partly due to the fact that the Swiffers effectively disintegrate during the extraction process so that no antigen was lost.

Statistical Analysis

We examined intrahouse, room-to-room correlation of Der-p-1 and Fel-d-1. Observed levels were not normally distributed, so a nonparametric approach (median concentrations and Spearman Rank Correlation coefficient) was employed to evaluate the data (SAS, PC Version 8). Medians and correlation coefficients were calculated first for all samples, assigning a value of 0 to those with nondetectable concentrations, and then recalculated excluding all samples with nondetectable concentrations, to demonstrate the quantitative relationship for samples with antigen. In addition, we dichotomized allergen levels as detectable or nondetectable, based on the minimum detectable concentration for each allergen assay, and calculated agreement (kappa) for room-to-room correlations, since a large proportion of homes had nondetectable allergen in at least some rooms. Finally, to further validate the measurements, we compared

Table 1Number of Households with Detectable¹ Allergen, Out of the 31 Households Tested

Allergen	Bedroom N (%)	Kitchen N (%)	Family Room N (%)
Total protein (mg/g)	31 (100%)	31 (100%)	30 (97%)
Der-p-1 (ug/g)	24 (77%)	22 (71%)	23 (74%)
Fel-d-1 (ug/g)	21 (68%)	20 (65%)	20 (65%)
Der-f-1 (ug/g)	5 (16%)	3 (1%)	10 (32%)
Bla-G-2 (ug/g)	5 (16%)	2 (0.06%)	11 (35%)

Note: ¹Above the minimum detectable sensitivity of the assay: Der-p-1 and Der-f-1 = 0.1 ug/g, Fel-d-1 = 0.03 ug/g, Bla-g-2 = 0.05 ug/g.

median levels of Fel-d-1 in homes of subjects who reported cat ownership (including all samples).

Results

Dust cloths were returned from each of the three designated rooms by 32 subjects within one month of mailing out the packages. Respondents consisted of both members of 10 twin pairs plus 12 additional single respondents. One third of the subjects resided in Southern California, one-third in Northern California, and the remainder were scattered throughout more rural areas of the state. The electrostatic cloths were received from one subject in unsealed plastic bags, and thus were considered contaminated and could not be used, so measurements were included from a total of 31 subjects' homes.

No antigens or protein were detected in the control Swiffers (the unused Swiffers returned in the unopened plastic bags). Allergen concentrations obtained using the two methods of standardization

were highly correlated. For example, the Spearman rank correlation coefficient for bedroom Der-p-1 and Fel-d-1 concentrations standardized as $\mu\text{g/g}$ of dust versus $\mu\text{g/g/ml}$ of protein, were 0.85 ($p < .0001$) and 0.94 ($p < .0001$), respectively. Because the results are so similar, we present the results using the $\mu\text{g/g}$ of dust standardization only.

Der-p-1 was the allergen most commonly present, followed by Fel-d-1 (Table 1). Within homes, measurable amounts of these allergens were found more often in bedrooms compared to other rooms. Allergens from the other species of dust mite (Der-f-1), and from cockroaches (Bla-g-2), were rarely found in homes within the detectable range, and when present, were found more often in family rooms. Measurable protein was found in essentially every house and every room, with the exception of one family room in one home.

Median Der-p-1 concentration (3.2 $\mu\text{g/g}$) was highest in bedrooms (Table 2). Fel-d-1 concentration was similar in kitchens and bedrooms, but lower in family rooms. The median concentration of Fel-d-1 was slightly less than that of Der-p-1, and the range was wider, suggesting greater variability. When samples with non-detectable allergen were excluded, the median concentrations of allergens were higher, ranging from 0.25 times higher for Der-p-1 (kitchens) to 14 times higher for Fel-d-1 (family rooms).

When all samples were included, Der-p-1 and Fel-d-1 concentrations were highly and statistically significantly correlated between rooms (Table 3). The highest correlation was observed for Fel-d-1 concentration in bedrooms vs. family rooms ($r = .74$, $p < .0001$; Table 3). Der-p-1 concentration was also highly correlated between bedrooms and family rooms ($r = .64$, $p = .0001$). When samples with nondetectable allergen

Table 2

Median Concentration of Allergen Levels in 31 Households from Mailed Wipe Test Collection

	Bedroom		Kitchen		Family Room	
	All Samples	Excluding ND	All Samples	Excluding ND ¹	All Samples	Excluding ND ¹
Total Protein (mg/g)						
Median	110.7	—	54.4	—	40.3	41.2
Q1 ²	45.6	—	27.3	—	12.0	16.2
Q3 ³	220.1	—	147.2	—	80.0	80.0
# ND	0	—	0	—	1	—
Der-p-1 (ug/g)						
Median	3.2	5.4	2.0	2.5	1.6	3.0
Q1 ¹	0.7	2.4	0.3	1.9	0.2	1.1
Q3 ²	8.6	9.2	2.6	3.0	6.5	9.0
# ND	7	—	9	—	8	—
Fel-d-1 (ug/g)						
Median	1.7	4.0	1.0	5.0	0.2	2.7
Q1 ¹	0.1	1.7	0.1	1.2	0.05	0.3
Q3 ²	16.7	25.8	12.9	23.4	3.8	7.8
# ND	10	—	11	—	11	—

Note: ¹ND = Non detectable

²first quartile (25%)

³third quartile (75%)

Table 3Intrahouse ($n = 31$) Correlation¹ (r) of Allergen Levels Self-Collected Using Mailed Wipe Tests

	Der-p-1 ($\mu\text{g/g}$)						Fel-d-1 ($\mu\text{g/g}$)					
	All Samples			Excluding ND ²			All samples			Excluding ND ²		
	n	r^1	p	n	r^1	p	n	r^1	p	n	r^1	p
Bedroom vs. kitchen	31	.61	.0003	21	.47	.030	31	.60	.0004	16	.73	.001
Bedroom vs. family room	31	.64	.0001	22	.39	.076	31	.74	<.0001	18	.40	.10
Family room vs. kitchen	31	.54	.002	19	.76	.0002	31	.64	.0001	16	.44	.090

Note: ¹Spearman rank correlation coefficient²ND = Non-detectable

were excluded, strong correlations persisted for most comparisons of allergen concentration between rooms found within a home. When allergen concentration was treated as a dichotomous variable (detectable vs. nondetectable), significant intrahouse, room-to-room agreement was observed for each combination of rooms (Table 4). As above, the highest agreement was found for Der-p-1 allergen concentration in bedrooms and family rooms ($k = .74$, $p < .0001$).

Questionnaire-reported cat ownership was associated with a large measured increase in Fel-d-1. The total home median concentration of Fel-d-1 among subjects reporting cats was 35.3 $\mu\text{g/g}$ compared to 1.6 $\mu\text{g/g}$ among subjects reporting no cats ($p = .005$).

Median concentration and intrahouse room-to-room correlations of Der-f-1 and Bla-g-2 are not presented, since so few houses were positive for measurable amounts of these antigens.

In the La Casa study comparison, the right and left halves of kitchens and bedrooms were highly correlated and statistically significant for Der-p-1 (r^2 for kitchens = .8, $p < .0001$; r^2 for bedrooms = .7, $p < .001$); Fel-d-1 (r^2 for kitchens = .7, $p < .0002$; r^2 for bedrooms = .7, $p < .0003$); and Bla-g-2 (r^2 for kitchens = .9, $p < .001$; r^2 for bedrooms = .9, $p < .0003$) measured from dust collected with electrostatic cloths by the same operator.

Discussion

Household allergens from participant-collected dust were successfully recovered from electrostatic cloths

used and returned by 31 subjects across California. The highest allergen concentrations were found in bedrooms. A previous study of Fel-d-1 levels in apartments in Germany found that allergen levels were similar in all rooms (Fahlbusch et al., 2002), but a study of Taiwanese asthmatic children found that for most of the year, children's bedrooms had the highest allergen levels compared to other rooms (Chen et al., 2002). A previous survey in California showed that mattress pads and bedroom floors at the head of the bed yielded significantly more dust mites than any other location in the home (Lang & Mulla, 1978). Thus, our Der-p-1 results correspond to those found in homes sampled in the same geographic area. The relative abundance of Der-p compared to Der-f in California has been reported previously (Furmizo, 1975).

In this demonstration project, allergen concentrations for the most common allergens Der-p-1 and Fel-d-1 were highly correlated in dust collections from different rooms in the same home, and in right and left halves of the same room in another set of homes. In addition, allergen concentration of Fel-d-1 was strongly associated with self-reported cat ownership. Although between-room correlation has not been used as a validation measure per se, other studies have compared correlations between devices in rooms in the same home, using the consistency of the correlations as evidence of validity of the collection method (Schram-Bijkerk et al., 2006). Although differences in operator performance could affect comparability, the high correlations within homes, and similarly high correlations in allergen measurements from both sides of a room, suggest that measurement error does not greatly affect the intrahouse correlations. Thus, in our study, there are few alternative explanations for the strong and consistent correlations observed for the most common allergens within homes, other than validity of the method.

Several other alternatives to household allergen collection using a vacuum cleaner have been assessed (Polzius et al., 2002; Sercombe et al., 2005). A quasi-real-time commercial instrument with visual display of allergen level has been developed (Drager Bio-Check Allergen Control; Polzius et al., 2002) and compared to vacuum-cleaner based sampling with mixed results (Polzius et al., 2002; Sercombe et al., 2005). One

Table 4Intraroom Agreement (k) by Detectability of Der-p-1 Allergen

	Kitchen $k(p)$	Family Room $k(p)$
Der-p-1		
Bedroom	.66 (.0002)	.74 (.0001)
Kitchen	—	.43 (.016)
Fel-d-1		
Bedroom	.35 (.049)	.64 (.0004)
Kitchen	—	.44 (.015)

Note: ¹ k = kappa statistic

shortcoming is that a separate device is necessary for each allergen of interest. Swedish investigators used a Petri dish placed in classrooms and homes and found a high correlation between allergen levels in personal air sampling devices and the Petri dish collections (Karlsson et al., 2002). This method, however, is not appropriate for assessing historical allergen levels or for mailed collections.

Sercombe and colleagues developed two nonvacuum methods for self-administered home allergen collection in epidemiological studies (Sercombe et al., 2005). One device consisted of a standardized length of adhesive tape, placed on fabric and carpet surfaces to collect samples. This approach did not correlate well with the vacuum method when results were analyzed by unit of dust (μg allergen per gram of dust; Sercombe et al., 2005). The second device was an electrostatic surface attached to a 25 cm² section of cardboard, which was used to wipe a uniform-sized area in bedrooms of various homes. The collected amounts of allergen correlated well with those collected by the standard vacuum method, but not with the amount from the press tape sampler.

Sercombe and colleagues (Sercombe et al., 2005) quantified their allergen collections in two ways — by adjusting for weight of total dust (μg allergen/g dust), and in terms of concentration per unit area ($\mu\text{g}/\text{m}^2$). We also standardized in two ways, by grams of dust and grams of protein; these two methods were highly correlated. (Standardization by weight has been recommended previously as more accurate than standardization by surface area; Doull et al., 1997.) We adjusted for total protein to partially correct for differences by operator. In addition, by including collections from floors and surfaces of rarely cleaned objects such as shelves and clocks, we obtained superficial and deep (historical) dust samples.

Because this study was a demonstration project and was not designed to test compliance, we did not report response rates, nor did we adjust for responses from both members of the same twin pair. Future validation studies of this method should include an evaluation of compliance as another measure of feasibility for use in mailed surveys.

Although we did not provide correlations against a standard dust collection method (vacuum), the vacuum method, although commonly used, in fact is not a gold standard. Previous studies have shown relatively large variances in allergen concentration measurement with vacuum methods (Marks et al., 1995). Sercombe and colleagues acknowledged that there is ‘no single validated method of sampling reservoir dust to maximize relevance to clinical outcomes’ (Sercombe et al., 2005). There is a consensus that absolute allergen concentration cannot be compared in studies that use different methods (Sercombe et al., 2005; Wickens et al., 2004). Therefore, for epidemiologic studies, relative comparisons using these measures makes the most sense. In this context, we

would use this collection method to compare relative concentrations of household allergens in twin pairs discordant for atopic conditions, to determine if household allergens predict atopy in twins.

Improvements to the procedure could be made to facilitate comparisons from measurements by different operators. However, the results of this demonstration project suggest that our participant-collected dust wipe method merits further study. In conclusion, non-intrusive and low-cost samples of dust, collected by study participants, using commercially available electrostatic dust cloths, and returned by conventional mail, is a promising alternative to technician-collected vacuumed dust for measuring indoor allergens in population-based studies.

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