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A comparison of subject room dust with home vacuum dust for evaluation of dust-borne aeroallergens

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Abstract

Background: Assessment of indoor allergen is valuable in exposure research and evaluation of allergic individuals. Collection methods range from grab vacuum samples to filtration devices located in the breathing range of an individual. For practical purposes, many research studies use analysis of collected house dust to evaluate allergen reservoirs.

Objective: To test the hypothesis that house dust collected from the family vacuum is equivalent to house dust collected by a technician following standard protocol.

Methods—Homes from a healthy homes demonstration project ($n = 41$) were sampled using a specific Department of Housing and Urban Development–suggested protocol in the bedroom of the child with asthma and a simple grab procedure from the family vacuum. Samples were evaluated for the presence of 5 allergens, Bla g2, Can f1, Der f1, and Der p1 combined as total mite, Fel d1, and Mus m1. Samples were also evaluated for total antigenic protein from 4 fungal taxa, including *Alternaria*, *Aspergillus*, *Cladosporium*, and *Penicillium*.

Results: All of the allergens and antigens tested showed good correlation between the 2 collection methods. Fungal antigens ranged up to 92,651 nanograms per gram of dust for *Aspergillus*, and allergens ranged up to 17,928 nanograms per gram of dust for Can f1. The best correlation was for *Cladosporium* ($r = 0.91$), and the weakest was for dust mite ($r = 0.34$).

Conclusion: Allergens and antigens tested from samples collected by protocol and by grab sampling from the home vacuum were highly positively correlated. Grab samples taken from the family vacuum may be a good surrogate for evaluating home allergen exposure.

Introduction

Domestic allergen exposures remain at the top of the list of controllable factors related to asthma in children.¹ Measurement of allergen proteins in house dust has been very useful in identifying environmental agents that are at the root of human allergic disease and function to trigger asthma attacks. From the beginning of allergen measurements in house dust,² there has been discussion as to the best collection methods and which collection protocols are most representative of human exposure. The most accurate method, however, is still not known.^{3,4} In light of the need for frequent monitoring to adequately assess exposure and gauge potential reductions that might lead to asthma symptom reduction, the practicality of patient-collected dust samples for allergen testing has been proposed.

The measurement of allergen reservoir levels is an important aspect of effective allergen trigger control. The cost effectiveness of allergen reduction and thereby the utility of allergen measurements has been demonstrated previously.⁵ In 1 study of improved asthma as a result of environmental control, within the intervention group there was a significant relationship between the reduction of dust aeroallergens and asthma symptom improvement.⁶ Allergen measurements were repeated every 6 months, and results from aeroallergen testing were used as part of motivational education and modeled behavioral changes to reduce aeroallergen exposures. Even though it has not been possible to consistently demonstrate the effectiveness of isolated allergen trigger control strategies,⁷ numerous studies have shown targeted interventions involving multiple control strategies to be effective in reducing asthma symptoms and health care use.^{6,8-10}

In this work, we aim to determine the relationship between allergen content in dust collected by a field worker according to a specific protocol and samples a patient could take from their home vacuum. We hypothesize that a dust sample collected from the home vacuum unit of a family, assuming the unit is used regularly and only in the home, would be a good proxy for that collected by a trained investigator.

Methods

Home selection and characteristics

Homes in this study were a subset of homes that participated in the Kansas City Safe and Healthy Homes Program. Homes participating in this program had at least 1 child with asthma resident for a minimum of 4 days per week. Asthma severity ranged from mild to severe. Homes in the program were assessed by environmental health professionals before and after a series of targeted interventions designed to improve the indoor air quality of the home. Homeowners received a new vacuum cleaner at the beginning of the study along with an assortment of useful cleaning supplies. Financial support was provided by the Department of Housing and Urban Development as a Healthy Homes Initiative Demonstration Grant awarded to Children's Mercy Hospital to provide for home and health assessments and analytical services. The home environment was assessed using a specific set of on-site and laboratory sampling and analyses.¹¹ All human subject elements of this study were reviewed and approved by the Institutional Review Board of Children's Mercy Hospital, and written informed consent was obtained from participants.

Dust collection

During the final inspection, a sample of dust of approximately 1 cubic decimeter was taken from the family vacuum unit, and a simultaneous sample was collected from the subject child's bedroom following a standardized protocol recommended by the Department of Housing and Urban Development (http://portal.hud.gov/hudportal/documents/huddoc?id=DOC_12539.pdf). The family was questioned to determine whether the vacuum unit had been used only in the home. The standardized protocol involved vacuuming 9 square feet of the child's bedroom, including bedding, rugs, carpet, and hard flooring, into a dust collection sample bag (x-cell-100, Midwest filtration, Cincinnati, Ohio).

Assays

Dust samples were returned to the laboratory and stored at -20°C until processed. Samples were sieved through a 300-mesh sieve (Thermo Fisher Scientific, Waltham, Massachusetts), and 200 mg sieved dust was extracted in 2.0 mL phosphate-buffered saline (PBS) for 4 hours with continuous agitation. Extracts were filtered ($5\ \mu\text{m}$) to remove particulates and stored at 4°C for no more than 24 hours before they were analyzed by immunoassay for allergens Fel d1, Can f1, Mus m1, Der f1, Der p1, and Bla g2 using standards, monoclonal and polyclonal

antibodies obtained from Indoor Biotechnologies (Chantilly, VA). Extracts were also analyzed for whole species antigens from fungi, including *Alternaria alternata*, *Aspergillus fumigatus*, *Cladosporium herbarum*, and *Penicillium chrysogenum*. These antigens were determined using polyclonal antibodies and standards obtained from Greer Laboratories (Lenoir, North Carolina).⁹ Results of all immunoassays were displayed as nanograms per gram of sifted dust for purposes of analysis.

Data and statistics

Descriptive statistics were computed using an Excel spreadsheet (Microsoft Corporation, Redmond, Washington), and comparative statistics were computed using the SPSS software (IBM Corporation, Armonk, New York). Two-tailed bivariate Pearson Correlation Coefficients and significance levels were calculated from variable values for dust analysis for each of the measured allergens and antigens comparing the home vacuum samples with the samples collected from the child's room. A *P* value of less than .05 was considered to be a significant correlation beyond a chance occurrence.

Results

The Healthy Homes Demonstration project screened a total of 1,473 families for enrollment, of which 382 families were enrolled and 302 families completed the study. Reasons for not enrolling in the study included failure to complete enrollment information, income greater than 80% of median family income (Department of Housing and Urban Development stipulation for participation), and plans to relocate during the time of the study. Reasons for not completing the study included repeated failure to meet appointments and unplanned relocation. Simultaneous sample sets from home vacuum and child's bedroom were obtained for 41 homes. Samples were collected randomly at the convenience of the home evaluator and the availability of sufficient sample in the vacuum unit. Mean values for these homes are within 1 standard deviation of the mean values obtained for all samples collected during the study (data not shown). Descriptive statistics for dust antigen and allergen values are shown in Table 1. All values are displayed as nanograms of allergen/antigen per gram of sifted dust. All of the measured allergens/antigens from family vacuum samples and samples collected specifically in the bedroom of the child with asthma were positively correlated at a significant level ($R > 0.33$; $P < .03$). All of the fungal antigen levels as well as the Bla g2, Can f1, Fel d1, and Mus m1 allergen levels were highly correlated ($R > 0.62$; $P < .001$), and the combined dust mite (Der f1 and Der p1) allergen levels were moderately well correlated ($R = 0.339$; $P < .05$). Figure 1 demonstrates the closeness of the mean values for the 2 sampling scenarios in the 41 homes. Figure 2 demonstrates the correlation between values obtained from home vacuums and children's bedrooms. For most of the allergens and antigens, the relationship is very linear, with a nearly 1-to-1 ratio.

Discussion

Early reviews on home allergen measurement used polyclonal antibodies and expressed results per square meter.¹² Subsequent discussion as to practical methods for dust sampling has been extensive.¹³ A continuously operating filter device worn on the collar or a particle retaining device worn in the nose constitutes the gold standard of exposure monitoring. In light of the reduced practicality of these devices, measurement of allergens from vacuum-collected house dust has become the most commonly used method to evaluate exposure.¹⁴ Comparison studies have indicated that household vacuum cleaners are reasonable alternatives to high-volume samplers for detecting, ranking, and quantifying pesticides and other compounds in carpet dust.¹⁵

Researchers have demonstrated that vacuum samples, whether from a special filter bag, a regular filter bag, or a regular bag upright unit, all produced samples sufficient for identification of mite exposure.¹⁶ The Isaac study used vacuumed dust from beds and floors as a surrogate for exposure.¹⁷ The first lead and allergens study also used dust collected with a small vacuum unit from 5 to 6 different areas of the home.¹⁸ In a study of 4 different sampling methods (airborne, settling in Petri dish, settling on sticky surface, and reservoir by vacuum), dust mite allergen in the reservoir dust collected by vacuum did not correlate well with any of the other collections.¹⁹ A study of home occupant-collected house dust and fieldworker collected samples indicated that levels of allergens in samples taken by study participants are moderately to highly correlated to levels in samples taken by fieldworkers.²⁰ Although there can be differences between collection devices, for example, nylon socks collected more dust than cloth material based devices,²¹ the presentation of results in a concentration format (micrograms of allergen per gram of dust) is expected to smooth these differences. Allergen and measurements in vacuumed dust have been the mainstay of allergen avoidance studies.^{22, 23} For practical reasons, a vacuum dust collection by a technical professional following a standardized protocol during a home visit has been adopted for many large epidemiological studies.^{24,25}

Vacuumed dust measurements are not a perfect proxy for allergen exposure. The quantity of allergen present in a dust reservoir and the composition of the dust matrix²⁶ represent only a few of several variables involved. Factors such as air circulation, percentage of fresh air, household activity levels,²⁷ disturbances, number of occupants, cleaning practices, and time spent in the home all impact actual exposures. Allergen measurements in vacuum dust only provide an indication of reservoir allergen and potential exposure.¹ Just as a negative result on a skin test has a high negative predictive value for the presence of allergy,²⁸ a high dust reservoir result for an allergen is a strong positive predictor for exposure. More reliable methods for measurement of personal exposure are available. Personal samplers have been used for many years²⁹; particle collectors are available for insertion into the nose of an allergic person.²⁷ All of these methods have their advantages and their drawbacks; however, collection and analysis of vacuumed dust remains very practical and easily accomplished.

In the present study we hypothesized that a dust sample collected from the home vacuum unit of a family would be a good proxy for that collected by a trained investigator using a common protocol. Similar investigations have been reported previously. Arbes et al³⁰ examined the feasibility of subject-collected dust for epidemiological and clinical studies and found it to be a viable and practical option. Van Dyke et al³¹ evaluated the ability of a resident to evaluate their home compared with evaluation and collection of settled dust by an industrial hygienist.³¹ They reported that residents can reliably collect settled dust samples.

House dust measurements are used to represent exposure not only in allergen studies but also in cancer and chemical exposure studies.^{15,32,33} Depending on the nature of the reservoir, house dust can reflect historic exposure levels over multiple years. Even though vacuumed dust only indicates potential, and better methods of personal exposure assessment are needed, from a practical and utilitarian point of view vacuumed dust remains a very valuable matrix for the evaluation of allergen exposure.¹⁹

This study supports previous studies investigating the relationship between dust collected from the home vacuum and dust collected by a trained technician using a specified protocol. Van Dyke et al³¹ studied the efficacy of occupant-collected dust samples in the evaluation of residential allergen and fungal levels. They reported that subject-collected dust allergen levels and technician-collected samples were highly correlated and in categorical (high, medium, or low) agreement for 76% of residences.³¹ Twiggs et al¹⁶ compared levels of mite allergen collected by a standard vacuum cleaner with a disposable bag with those collected

by a hand-held vacuum equipped with a special filter. They concluded that dust mite allergen levels collected in a disposable bag vacuum cleaner were reliable indicators of the of home house dust mite levels.¹⁶ Schram-Bijkerk et al²⁰ studied dust collection methods conducted by participants and fieldworkers and concluded that dust collection by participants is a reliable and practical option for allergen and microbial agent exposure assessment.²⁰ Other studies have examined the relative positional concentrations or allergens within housing. Giovannangelo et al³⁴ determined the within-home and between-home variance of a number of biocontaminants in house dust and noted that the within-home variance was small compared with the between-home variance for allergens measured. Wickens et al²¹ tested different sampling methods and suggested that standardization in the use of sampling equipment is important for the collection of allergen and endotoxin.²¹ However, Mansour et al⁴ compared the association of measured allergen exposure and serum-specific immunoglobulin E levels with 3 sampling methods. They found that allergen concentration did not differ significantly by sampling method.

Our studies indicate a very strong correlation between samples collected from vacuum bags and samples collected by technicians from subject bedrooms. The correlations, ranging from 0.34 to 0.91 with the sample size of 41, are at least good and at best very strong. It is not surprising that dust mite would have the weakest correlation because it is strongly associated with bedding; however, dust mites can also be associated with any location at which humans or animals spend time.¹⁴ The particles associated with mites are also large and reportedly do not spend much time airborne after they are disturbed.³⁵ The limiting factor in the correlation of these allergen measurements in dust might be the assays. Dust has great fluctuation in matrix material. The presence of cleaning and freshening material in dust inhibits dust mite assays.²⁶ The matrix effect is also important in that some samples contain a large proportion of sand or metallic fragments, causing the sample to be heavier in relation to allergen present. Because results are displayed as allergen per gram of house dust, when the weight of the dust increases, the relative allergen measurement decreases.¹⁴ Likewise, fungi should have some of the best correlations, because they are evolved to spread through the air and distribute evenly around the house.

In conclusion, analysis results for allergens and antigens from 9 different common indoor sources in samples collected by protocol from the pediatric subject's room and by grab sampling from the home vacuum unit were highly positively correlated. Grab samples taken from the family vacuum may be considered a good surrogate for evaluating "in home" allergen exposure.

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References

1. Tovey E, Ferro A. Time for new methods for avoidance of house dust mite and other allergens. *Current Allergy and Asthma Reports*. 2012; 12:465–477. [PubMed: 22833251]
2. Tovey ER, Chapman MD, Wells CW, Platts-Mills TA. The distribution of dust mite allergen in the houses of patients with asthma. *Am Rev Respir Dis*. 1981; 124:630–635. [PubMed: 7305119]
3. Mosbech H, Lind P. Collection of house dust for analysis of mite allergens:allergen-reducing effect of a self-administered procedure. *Allergy*. 1986; 41:373–378. [PubMed: 3532859]

4. Mansour M, Lanphear BP, Hornung R, et al. A side-by-side comparison of sampling methods for settled, indoor allergens. *Environ Res.* 2001; 87:37–46. [PubMed: 11534963]
5. Kattan M, Stearns SC, Crain EF, et al. Cost-effectiveness of a home-based environmental intervention for inner-city children with asthma. *J Allergy Clin Immunol.* 2005; 116:1058–1063. [PubMed: 16275376]
6. Morgan WJ, Crain EF, Gruchalla RS, et al. Results of a home-based environmental intervention among urban children with asthma. *N Engl J Med.* 2004; 351:1068–1080. [PubMed: 15356304]
7. Gotzsche PC, Johansen HK. House dust mite control measures for asthma. *Cochrane Database Syst Rev.* 2008; (2):CD001187. Epub 2008/04/22. [PubMed: 18425868]
8. Johnson L, Ciaccio C, Barnes CS, et al. Low-cost interventions improve indoor air quality and children's health. *Allergy Asthma Proc.* 2009; 30:377–385. [PubMed: 19772759]
9. Barnes CS, Kennedy K, Gard L, et al. The impact of home cleaning on quality of life for homes with asthmatic children. *Allergy Asthma Proc.* 2008; 29:197–204. [PubMed: 18336723]
10. O'Sullivan MM, Brandfield J, Hoskote SS, et al. Environmental improvements brought by the legal interventions in the homes of poorly controlled innercity adult asthmatic patients: a proof-of-concept study. *The Journal of Asthma: Official Journal of the Association for the Care of Asthma.* 2012; 49:911–917. [PubMed: 23020301]
11. Portnoy JM, Flappan S, Barnes C. A standardized procedure for evaluation of the indoor environment. *Aerobiologia.* 2001; 17:43–48.
12. Dreborg S. Mite allergens: collection, determination, expression of results, and risk levels for sensitization and symptom induction. *Allergy.* 1998; 53(48 Suppl):88–91. [PubMed: 10096816]
13. Tovey ER, Marks GB. It's time to rethink mite allergen avoidance. *J Allergy Clin Immunol.* 2011; 128:723–727. [PubMed: 21855978]
14. Platts-Mills TA, Thomas WR, Aalberse RC, Vervloet D, Chapman MD. Dust mite allergens and asthma: report of a second international workshop. *J Allergy Clin Immunology.* 1992; 89:1046–1060. [PubMed: 1349902]
15. Colt JS, Gunier RB, Metayer C, et al. Household vacuum cleaners vs. the highvolume surface sampler for collection of carpet dust samples in epidemiologic studies of children. *Environmental Health.* 2008; 7:6. 2008/02/23. [PubMed: 18291036]
16. Twiggs JT, Gray RL, DeJongh S, Marx JJ Jr. *Dermatophagoides farinae* allergen levels from two different sources within the same home: evaluation of two different collection techniques. *Ann Allergy.* 1991; 66:431–435. [PubMed: 2035907]
17. Gehring U, Strikwold M, Schram-Bijkerk D, et al. Asthma and allergic symptoms in relation to house dust endotoxin: Phase Two of the International Study on Asthma and Allergies in Childhood (ISAAC II). *Clin Exp Allergy.* 2008; 38:1911–1920. [PubMed: 18771486]
18. Vojta PJ, Friedman W, Marker DA, et al. First National Survey of Lead and Allergens in Housing: survey design and methods for the allergen and endotoxin components. *Environmental Health Perspectives.* 2002; 110:527–532. [PubMed: 12003758]
19. Tovey ER, Mitakakis TZ, Sercombe JK, Vanlaar CH, Marks GB. Four methods of sampling for dust mite allergen: differences in 'dust'. *Allergy.* 2003; 58:790–794. [PubMed: 12859560]
20. Schram-Bijkerk D, Doekes G, Boeve M, et al. Exposure to microbial components and allergens in population studies: a comparison of two house dust collection methods applied by participants and fieldworkers. *Indoor Air.* 2006; 16:414–425. [PubMed: 17100663]
21. Wickens K, Lane J, Siebers R, Ingham T, Crane J. Comparison of two dust collection methods for reservoir indoor allergens and endotoxin on carpets and mattresses. *Indoor air.* 2004; 14(3):217–222. [PubMed: 15104790]
22. Tovey ER, Chapman MD, Platts-Mills TA. Mite faeces are a major source of house dust allergens. *Nature.* 1981; 289(5798):592–593. [PubMed: 7464922]
23. Mansfield LE, Nelson HS. Allergens in commercial house dust. *Annals of allergy.* 1982; 48(4): 205–209. [PubMed: 7073022]
24. Mitchell H, Senturia Y, Gergen P, et al. Design and methods of the National Cooperative Inner-City Asthma Study. *Pediatric pulmonology.* 1997; 24(4):237–252. [PubMed: 9368258]
25. Weiland SK, Bjorksten B, Brunekreef B, Cookson WO, von Mutius E, Strachan DP. Phase II of the International Study of Asthma and Allergies in Childhood (ISAAC II): rationale and methods.

- The European respiratory journal: official journal of the European Society for Clinical Respiratory Physiology. 2004; 24(3):406–412.
26. Chew GL, Higgins KM, Milton DK, Burge HA. The effects of carpet fresheners and other additives on the behaviour of indoor allergen assays. *Clinical and experimental allergy: journal of the British Society for Allergy and Clinical Immunology*. 1999; 29(4):470–477. [PubMed: 10202361]
 27. Gore RB, Hadi EA, Craven M, et al. Personal exposure to house dust mite allergen in bed: nasal air sampling and reservoir allergen levels. *Clinical and experimental allergy: journal of the British Society for Allergy and Clinical Immunology*. 2002; 32(6):856–859. [PubMed: 12047431]
 28. Bodtger U, Assing K, Poulsen LK. A prospective, clinical study on asymptomatic sensitisation and development of allergic rhinitis: high negative predictive value of allergological testing. *International archives of allergy and immunology*. 2011; 155(3):289–296. [PubMed: 21293149]
 29. Chatterjee BB, Williams MK, Walford J, King E. The location of personal sampler filter filter heads. *American Industrial Hygiene Association journal*. 1969; 30(6):643–645. [PubMed: 5369280]
 30. Arbes SJ Jr, Sever M, Vaughn B, et al. Feasibility of using subject-collected dust samples in epidemiologic and clinical studies of indoor allergens. *Environmental health perspectives*. 2005; 113(6):665–669. [PubMed: 15929886]
 31. Van Dyke MV, Martyny JW, Marola J, et al. Efficacy of occupant-collected dust samples in the evaluation of residential allergen and fungal levels. *J Occup Environ Hyg*. 2012; 9:14–24. [PubMed: 22150472]
 32. Whitehead T, Metayer C, Ward MH, et al. Is house-dust nicotine a good surrogate for household smoking? *Am J Epidemiol*. 2009; 169:1113–1123. [PubMed: 19299402]
 33. Hsu NY, Lee CC, Wang JY, et al. Predicted risk of childhood allergy, asthma, and reported symptoms using measured phthalate exposure in dust and urine. *Indoor Air*. 2012; 22:186–199. [PubMed: 21995786]
 34. Giovannangelo M, Nordling E, Gehring U, et al. Variation of biocontaminant levels within and between homes: the AIRALLERG study. *J Exposure Sci Environ Epidemiol*. 2007; 17:134–140.
 35. Platts-Mills TA, Vervloet D, Thomas WR, Aalberse RC, Chapman MD. Indoor allergens and asthma: report of the Third International Workshop. *J Allergy Clin Immunol*. 1997; 100(6 Pt 1):S2–24. [PubMed: 9438476]

Figure 1.
Allergen measurements taken from the home vacuum grab sample and the child's bedroom.

Figure 2.

Correlation of allergen measurements using scatter diagrams. The home vacuum dust allergen measurement is plotted on the vertical axis, and the child's bedroom dust allergen measurement is plotted on the horizontal axis. The Can f1 and Bla g2 allergens have the best correlation, whereas the combined dust mite (Der f1 + Der p1) measurements have a somewhat lower correlation.

Table 1

Allergen/antigen levels in subject homes

Allergen	Child BR Max	Child BR Mean (SD)	Home Vac Max	Home Vac Mean (SD)	Correlation	Significance
Alternaria	21,931	3,752 (4,910)	4,3571	7,104 (9,648)	0.681	<.001
Aspergillus	92,651	11,063 (20,553)	113,218	12,302 (26,880)	0.859	<.001
Bla g2	2,961	246 (521)	14,982	593 (2,353)	0.872	<.001
Can f1	17,928	1,524 (3,647)	36,923	2,248 (6,023)	0.816	<.001
Cladosporium	74,755	11,419 (15,719)	74,396	13,055 (17,844)	0.913	<.001
Dust mite	4,672	615 (932)	3,237	721 (932)	0.339	.030
Fel d1	12,675	952 (2,539)	16,315	739 (4,496)	0.620	<.001
Mus m1	1,759	248 (450)	2,309	315 (453)	0.746	<.001
Penicillium	36,694	6,411 (9,016)	48,816	8,410 (11,118)	0.845	<.001

All values are displayed as nanograms of allergen/antigen per gram of sifted dust.