
Classroom aeroallergen exposure in Arkansas Head Start centers

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Background: The impact of preschool environmental conditions on classroom aeroallergen concentrations is not fully understood.

Objective: To examine the relationship between school environmental conditions and classroom aeroallergen concentrations in the Pulaski County Head Start (HS) Program.

Methods: Thirty-three HS centers in Pulaski County, Arkansas, underwent a detailed environmental evaluation. Classroom settled dust samples were analyzed for the presence of common indoor allergens.

Results: Classroom eating (70%), wall-to-wall carpeting (58%), and water damage (33%) were common. Median classroom allergen levels were as follows: dust mite (Der p 1 and Der f 1), 0.6 $\mu\text{g/g}$; Fel d 1, 0.4 $\mu\text{g/g}$; Can f 1, 1.7 $\mu\text{g/g}$; cockroach, below detection; Mus m 1, 0.18 $\mu\text{g/g}$; and mold spores, 17,800 CFU/g. Can f 1 and Mus m 1 allergens were detected in 100% of HS centers. Facilities with carpeting, increased humidity, and single-use facilities showed trends toward increased dust mite concentrations. Detectable cockroach allergen was more common in classrooms cleaned by teachers than by professional housekeepers.

Conclusions: Aeroallergens were commonly detected in Pulaski County HS center classrooms, with dog and mouse allergens detected in 100% of centers. Median classroom allergen concentrations were low, and classroom characteristics were not strongly predictive of increased allergen exposure.

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INTRODUCTION

Environmental exposure to allergens has been associated with allergic sensitization and the development of asthma.^{1,2} In sensitized individuals, aeroallergen exposure has been related to increased asthma severity and increased morbidity.^{3–6} Previous aeroallergen-related research has focused primarily on the importance of home allergen exposure, and studies on the significance of environmental conditions and aeroallergen concentrations in the preschool environment are limited. Preschoolers with recurrent wheezing are at significantly higher risk for persistent asthma,⁷ and previous studies^{8–10} have found the preschool years to be the time during which important changes in lung function occur in individuals who ultimately develop persistent asthma.

Preschoolers spend a substantial portion of their time, and in some cases the entire day, in the same classroom. Because the

preschool years are a critical time during which specific IgE-mediated sensitivity to aeroallergens is developed,¹¹ aeroallergen exposure in the preschool environment could facilitate allergic sensitization and lead to subsequent development of asthma. There have been studies^{12,13} of exposure to clinically relevant concentrations of aeroallergen in day care and school environments. Arbes et al¹² found that aeroallergen concentrations in North Carolina day care facilities are similar to levels in southern US homes. These results suggest that sensitization risks at day care centers are similar to those at home. Amr and colleagues¹⁴ identified a positive correlation between asthma prevalence and cockroach allergen exposure in inner-city elementary schools. Both of these studies support the hypothesis that exposure to aeroallergens in environments outside the home may be clinically relevant and require further investigation. Currently, the relationship between school environmental characteristics and classroom aeroallergen exposure in suburban and non-inner-city preschool classrooms has not been adequately characterized. The aim of the present study is to evaluate the relationship between preschool environmental conditions and aeroallergen concentrations in the classrooms of the Pulaski County Head Start (HS) Program in central Arkansas.

METHODS

HS Facilities

Head Start is a federally funded early childhood education program for children of disadvantaged families. The 33 HS facilities participating in the present study are located in the central region of Arkansas in Pulaski County. Permission to

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perform school inspections and collect settled dust samples for aeroallergen analysis was obtained from school administrative personnel. Participating schools were part of a large prospective asthma educational intervention in the HS population. The study was approved by University of Arkansas for Medical Sciences institutional review board.

Environmental Survey

An independent environmental consulting firm performed inspections between April 1 and June 30, 2003, to evaluate the physical design of each HS facility. The heating, ventilation, and air-conditioning components were examined, as were the structure, location, and general condition of each facility. A detailed evaluation of the classroom environment was performed, including measurement of temperature and humidity (Digital Hygro-Thermometer; ExTech Instruments, Waltham, Massachusetts), documentation of odors, types of floor coverings, and the presence of upholstered furniture, stuffed toys, plants, or pets. Evidence of insects or pests and the presence of water damage were recorded. Activities occurring in the classrooms were documented, including length and location of naps, hours spent sitting on carpeted floors or rugs, classroom eating, and classroom cleaning routines.

Settled Dust Collection and Processing

Settled dust was collected from HS classrooms by a trained technician between April 1 and June 30, 2003, using a commercial hand-held vacuum (model C2094; Hoover, Canton, Ohio) equipped with a collection sleeve using previously published methods.^{15,16} At each HS facility, dust samples from individual classrooms were obtained collectively in a single collector and labeled with a unique 3-digit identifier. Each room was vacuumed for 1 to 2 minutes starting around the perimeter and moving to the center of the room, including under furniture. Preference was given to the perimeter of carpeted rooms or rugs overlying bare floors. The vacuum head was cleaned using disinfecting wipes (Clorox Wipes; Clorox Co, Oakland, California) and dried using a paper towel each time the collection sleeve was changed.

After collection, dust samples were maintained at -20°C until they were sent to the Johns Hopkins Dermatology Allergy and Clinical Immunology Laboratory for extraction and aeroallergen analysis. The crude dust specimen was initially sieved through a 50-mesh device, which permitted particles larger than $300\text{ }\mu\text{m}$ to pass onto the filter paper. The fine (sieved) dust was then weighted, and 100 mg was extracted overnight at room temperature with 2 mL of borate-buffered saline containing 5% bovine serum albumin. Extracts were then centrifuged, and the supernatant was sterile filtered before being analyzed for Bla g 1, Bla g 2, Mus m 1, Can f 1, Fel d 1, Der p 1, and Der f 1 in 2-site monoclonal antibody-based enzyme-linked immunosorbent assays (Indoor Biotechnologies, Charlottesville, Virginia).¹⁷⁻²¹ Aeroallergen results are reported as micrograms of allergen per gram of dust. The quantitative microgram-per-gram allergen levels were assigned to 1 of several categories based on previously defined allergen ranges: undetectable, low, or high.²²

To evaluate mold content in each facility, dust samples were analyzed as previously described for the number of viable spores per gram of dust.²² Briefly, 5 mg of fine dust was aseptically layered on a Sabouraud Dextrose agar plate containing selected antibiotics to prevent bacterial growth. The inverted plate was incubated at 21°C , and the number of colonies was quantified at 36 hours. Final colony counts were corrected for sample size, and the results were reported as the number of viable colonies per gram of dust.

Statistical Analysis

All the analyses were performed using a software program (SPSS version 15; SPSS Inc, Chicago, Illinois). Medians (ranges) were used to summarize allergen levels. Allergen concentrations were categorized as undetectable, low, or high exposure levels. Nonparametric Mann-Whitney tests were used to compare allergen levels for the presence and absence of classroom conditions. Cross-tabulations using Fisher exact tests were analyzed for categorized allergen levels and environmental conditions, such as carpet and eating in the classroom. To evaluate the contribution of all the factors together, logistic regression was performed using the categorized allergen levels as outcomes and the classroom conditions as covariates. No interaction terms were considered. A 2-tailed $P < .05$ was considered statistically significant.

RESULTS

Environmental Characteristics of HS Facilities

Most of the HS centers were in nonurban locations with 8 urban, 19 suburban, and 6 rural centers (Table 1). Sixty-one percent of the HS centers were housed in large multiuse facilities, such as an elementary school, a church, or an office building, whereas 39% of the programs were housed in

Table 1. Characteristics of the 33 Head Start Facilities Studied

Characteristic	Facilities, No. (%)
Locale	
Urban	8 (24)
Suburban	19 (58)
Rural	6 (18)
Single-purpose building	13 (39)
Central heating and air-conditioning	32 (97)
Furry pets	1 (3)
Roach or glue traps present	9 (27)
Rodent droppings present	3 (9)
Wall-to-wall carpeting	19 (58)
Upholstered furniture	25 (76)
Professional housekeeping	22 (67)
Water damage	11 (33)
Musty/moldy odor	6 (18)
Plants in the classroom	16 (49)
Classroom eating	23 (70)
Time spent sitting on carpet daily, h	
<2	6 (18)
2-2.5	18 (55)
>2.5	9 (27)

single-use facilities. The results of the environmental survey revealed that all but 1 of the HS facilities had central heat and air-conditioning. The mean relative humidity was 48% (range, 34%–75%). One school had a rodent as a classroom pet; however, furry pets were not found in other schools. Nine (27%) of the sites had roach traps or glue traps, suggestive of cockroach problems. No evidence of live or dead cockroaches was observed. Mouse droppings were present in 3 (9%) of HS centers. Wall-to-wall carpet was found in 58% of the centers. Sixty-seven percent of the facilities were cleaned by professional housekeeping staff, and the other centers were cleaned by teachers or other nonjanitorial staff. Evidence of water damage was found in 33% of the centers, including water stains on floors, walls, or ceilings and leaks around sinks, faucets, or water fountains. Classroom eating was common, with 70% of the sites allowing students to eat lunch or snacks in the classrooms.

Distribution of Allergens in Settled Dust

The limit of allergen detection was 0.02 µg/g for Can f 1, Fel d 1, Der p 1, and Der f 1; 0.01 µg/g for Mus m 1; 0.4 U/g for Bla g 1; and 1 U/g for Bla g 2. Dust mite allergen (combined Der p 1 and Der f 1) was detectable in 27 of 33 (82%) of the HS centers, with a median concentration of 0.6 µg/g (Table 2). High dust mite concentrations (≥2 µg/g) were found in 11 of 33 centers (Fig 1A). Cat allergen was detected in 70% of the centers, and the median Fel d 1 concentration was 0.4 µg/g. High Fel d 1 concentrations (≥1 µg/g) were detected in 6 centers (Fig 1B). Dog allergen was found in 100% of the HS centers, and the median Can f 1 concentration was 1.7 µg/g, with high concentrations (≥2 µg/g) in 12 centers (Fig 1C). Mus m 1 was detected in all 33 centers, with a median concentration of 0.18 µg/g. High Mus m 1 concentrations (≥1.6 µg/g) were found in 1 center (Fig 1D). Cockroach allergens (Bla g 1 or Bla g 2) were detected in 7 (21%) of the centers, and the median concentration of both allergens was below detection. High cockroach concentrations (≥2 U/g) were found in 2 (6%) of the centers (Fig 1E). Mold spore counts could not be obtained on samples from 2 of the 33 centers secondary to the presence of bacterial overgrowth. Mold spores were detected in all 31 of the remaining centers, with a median mold spore count of 17,800 CFU/g (range,

1,800–83,600). High mold levels (>25,000 CFU/g) were identified in 8 centers (Fig 1F).

Environmental Conditions and Allergen Concentrations
In univariate analyses, the presence of wall-to-wall carpeting ($P = .03$), increased humidity ($P < .01$), and single-use HS facilities ($P < .01$) were associated with increased dust mite allergen concentrations. These variables did not remain significant in multivariate logistic regression models.

Increased pet, pest, and mold allergen concentrations were not associated with wall-to-wall carpeting. There was a trend suggesting that classrooms cleaned by teachers were more likely to have detectable cockroach allergen compared with those professionally cleaned ($P = .06$). Median allergen concentrations of dust mites, Can f 1, and Fel d 1 were statistically significantly lower in classrooms in which students were allowed to eat. However, Bla g 1, Bla g 2, and Mus m 1 allergen levels were not significantly increased in rooms in which students were allowed to eat. There was no association between mold levels and “musty” odor, evidence of water damage, or higher humidity.

DISCUSSION

Environmental allergens are associated with the development and exacerbation of asthma.^{4,6,23,24} We examined HS environments in Pulaski County where students spend 6 to 8 hours per day, Monday through Friday. The time children spend at the HS center is second only to the time spent in their primary place of residence, and it may account for significant exposure to aeroallergens. Detectable concentrations of perennial aeroallergens were found in most HS centers. Although concentrations were generally low, many sites had levels of exposure that have been previously associated with aeroallergen sensitization and asthma symptoms in sensitized individuals.^{25–27}

Mouse and dog allergens were detected in 100% of the centers; however, none of the environmental factors measured were significantly related to concentrations of mouse allergen, and lower dog allergen concentrations were associated only with classroom eating. The fact that detectable concentrations of these allergens were found in 100% of the centers may partly be due to transfer of allergens from home environments because few centers had evidence of mice on inspection, and none had dogs present. Data on home pets and pests were not available for the present study. Pet ownership has been linked to a higher socioeconomic status (SES), and findings by Arbes et al¹² suggested an association between day care facilities in North Carolina and markers of higher SES related to pet allergen concentrations. The Pulaski County HS population consists of students from a predominantly low SES population, and these findings provide further evidence of the ubiquitous nature of animal allergens as described by researchers.^{28–30}

A recent study¹⁴ in Baltimore public elementary schools identified 66% of the schools as having high levels of cockroach allergen, with mean Bla g 1 and Bla g 2 concentrations

Table 2. Distribution of Allergens in the 33 Head Start Facilities Studied

	Detectable, No. (%)	Median	Range
Dust mite, µg/g ^a	27 (82)	0.6	BD–22.0
Fel d 1, µg/g	23 (70)	0.4	BD–4.3
Can f 1, µg/g	33 (100)	1.7	0.1–33.6
Bla g 1, U/g	7 (21)	BD	BD–5.4
Bla g 2, U/g	2 (6)	BD	BD–1.4
Mus m 1, µg/g	33 (100)	0.18	0.02–1.7
Mold, CFU/g ^b	31 (94)	17,800	BD–83,600

Abbreviation: BD, below detection.
^a Combined Der p 1 and Der f 1.
^b Bacteria was detected in 2 samples.

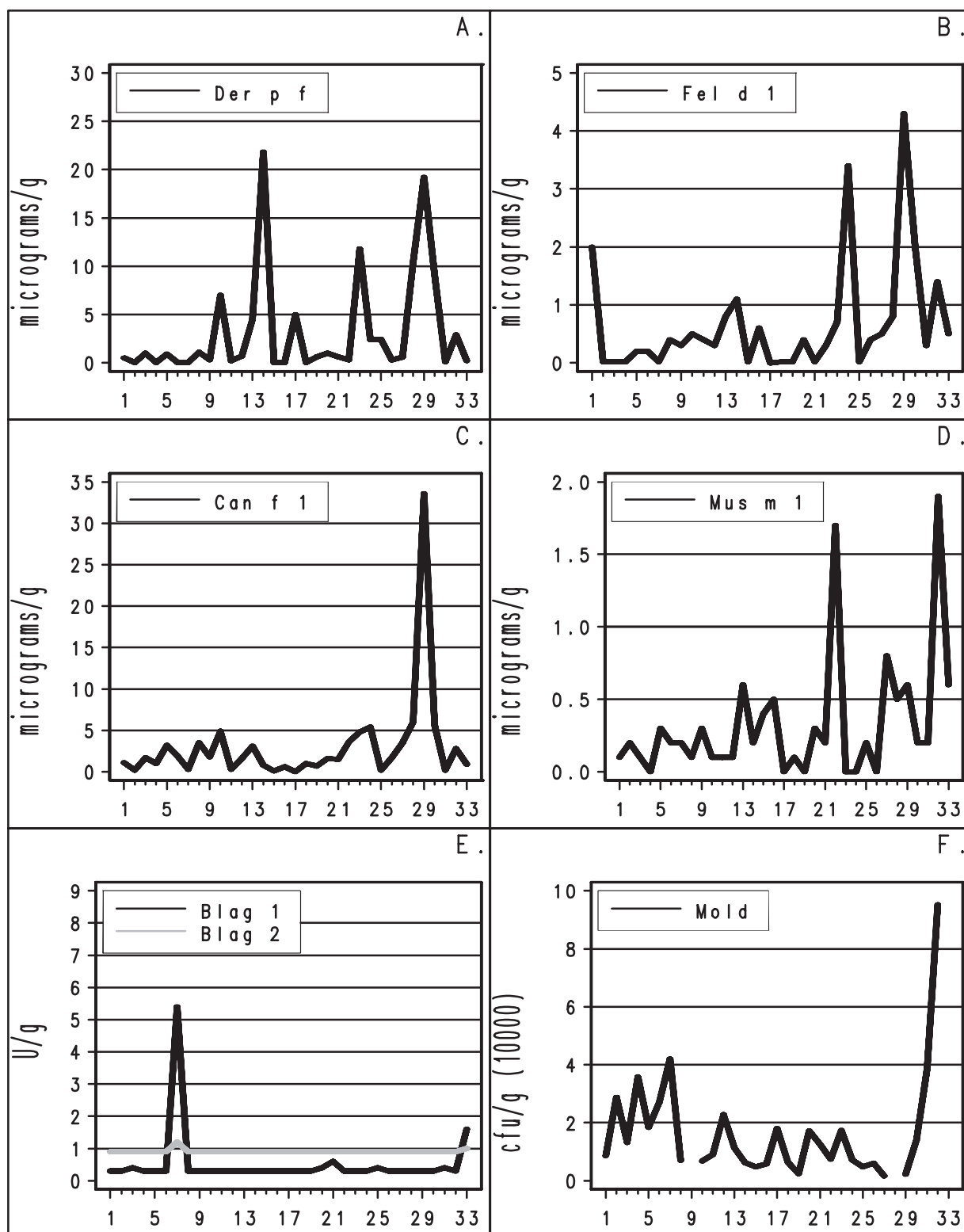


Figure 1. Allergen concentrations for each of the 33 Head Start centers. A, Combined Der p 1 and Der f 1 concentrations. B, Fel d 1. C, Can f 1. D, Mus m 1. E, Bla g 1 and Bla g 2. F, Mold. Mold readings from 2 sites were not obtained owing to bacterial overgrowth.

of 1.5 U/g. Their findings suggested a positive correlation between classroom cockroach aeroallergen exposure and asthma prevalence. Other investigators have found high rates of cockroach allergen detection in school and day care settings^{13,29}; however, detectable cockroach allergen (Bla g 1 or Bla g 2) was found in only 21% of Pulaski County HS centers. Because a previous study³¹ found cockroach allergen in schools to be more common in areas where food is present, we expected cockroach allergen to be more prevalent because classroom eating occurred in 70% of Pulaski County HS centers. The finding of undetectable cockroach allergen in most classrooms was reassuring and may be related to the fact that most of the HS centers were cleaned by professional housekeeping staff rather than by teachers. It is possible that more intense cleaning methods were used in areas where food remains were present. Also, these findings may differ from previous investigations that were performed in densely populated urban areas, where cockroach allergen is a predominant allergen in the homes.^{14,31,32} In these previous studies, evidence of cockroaches in the schools, such as the presence of live or dead cockroaches, cockroach stains, or sticky traps, was not documented; therefore, it is plausible that transfer of cockroach allergen from homes to school could have occurred in these highly endemic areas.

Dampness, including elevated humidity and evidence of water damage, has been associated with increased concentrations of mold.³³ Mold has been associated with increased asthma prevalence³⁴ and increased symptoms of asthma,³⁵ and recent attention has been given to the role of school exposure to mold in allergic diseases, such as asthma in schools.³⁶ We found no associations among humidity, water damage, and mold spore counts; however, humidity levels were measured only once during the study. Periodic humidity readings during different seasons of the year may have better defined a relationship between allergen content and humidity.

Rigorous housekeeping has been encouraged as a means of minimizing exposure to pet allergens³⁷; however, others have found no association between cat or dog allergen levels and the amount of cleaning.³⁸ Sixty-seven percent of the HS centers were cleaned by a professional housekeeping staff, and decreased pet or dust mite allergen levels were not significantly related to cleaning by professionals. We expected to find higher allergen levels in centers with wall-to-wall carpeting because it is a reservoir for allergens; however, the present models did not find a strong relationship. The failure to find a significant difference in allergen concentrations between centers with carpeting and those with hard flooring may be explained by a weakness in study design. Some centers did not have consistent flooring throughout the facility, and some rooms with hard flooring had overlying area rugs. Therefore, it is reasonable to presume that rooms with large area rugs might likely carry similar risks for increased allergen concentrations as rooms with wall-to-wall carpeting.

We previously reported on this Pulaski County HS population in central Arkansas and found it to be characterized by

multiple asthma risk factors, including most being African American (90%) and low income (84%).^{39,40} Previous studies by our group also revealed a high prevalence of aeroallergen sensitization (68%) in a subsample of HS children with asthma. We did not design the current study to evaluate the association between classroom allergen exposure, sensitization, and asthma prevalence; therefore, we cannot definitively comment on the effect of HS allergen exposure and asthma outcomes in this population. However, findings from the present study and other investigators^{12–14} suggest that the school environment is an important consideration in the evaluation and management of children with symptoms of allergic rhinitis and asthma. Allergen exposure in the school or day care setting may be related to poorly controlled symptoms or failure to observe improvements in symptoms when home allergen reduction measures have been conducted. Further research should focus on identifying the relationship between school allergen exposure and health outcomes. The school environment is potentially an important missing link in the pursuit of optimal primary and secondary prevention of allergic disease.

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