Original Article

School Environmental Intervention to Reduce Particulate Pollutant Exposures for Children with Asthma

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What is already known about this topic? Air cleaner interventions to reduce particulate pollutants at homes have been successful in improving indoor air quality and asthma morbidity in children. However, less is known about the school environment.

What does this article add to our knowledge? This study illustrates the feasibility and efficacy of a school-based air cleaner intervention to reduce classroom particulate pollutants. We found modest evidence of improved lung function.

How does this study impact current management guidelines? Air cleaners can reduce exposures to asthma-exacerbating pollutants present in indoor environments. This supports further evaluation of air cleaners as a classroom-based intervention to produce clinically meaningful improvements in asthma morbidity in children.

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BACKGROUND: Home-based interventions to improve indoor air quality have demonstrated benefits for asthma morbidity, yet little is known about the effect of environmental interventions in the school setting.
OBJECTIVE: We piloted the feasibility and effectiveness of a classroom-based air cleaner intervention to reduce particulate pollutants in classrooms of children with asthma.
METHODS: In this pilot randomized controlled trial, we assessed the effect of air cleaners on indoor air particulate pollutant concentrations in 18 classrooms (9 control, 9 intervention) in 3 urban elementary schools. We enrolled 25 children with asthma (13 control, 12 intervention) aged 6 to 10 years. Classroom air pollutant measurements and spirometry were completed once before and twice after randomization. Asthma symptoms were surveyed every 3 months.
RESULTS: Baseline classroom levels of fine particulate matter (particulate matter with diameter of <2.5 μm [$PM_{2.5}$]) and black carbon (BC) were 6.3 and 0.41 μg/m^3, respectively. When comparing the intervention to the control group, classroom $PM_{2.5}$ levels were reduced by 49% and 42% and BC levels were reduced by 58% and 55% in the first and second follow-up periods, respectively (P < .05 for all comparisons). When comparing the children randomized to intervention and control classrooms, there was a modest improvement in peak flow, but no significant changes in forced expiratory volume in 1 second (FEV_1) and asthma symptoms.
CONCLUSIONS: In this pilot study, a classroom-based air cleaner intervention led to significant reductions in $PM_{2.5}$ and BC. Future large-scale studies should comprehensively evaluate the effect of school-based environmental interventions on

Abbreviations used
BC- Black carbon
HEPA- High efficiency particulate air
IPM- Integrated pest management
PEF- Peak expiratory flow
$PM_{2.5}$- Particulate matter with diameter of less than 2.5 μm

pediatric asthma morbidity. **(J Allergy Clin Immunol Pract 2016;■:■-■)**

Key words: *Asthma; Indoor air quality; Environmental intervention; Air cleaner*

Asthma is one of the most common chronic diseases of childhood in the United States, affecting 13% of children living in urban areas.[1] Every year, asthma accounts for more than 10 million missed school days in the United States.[1] Urban minority populations experience greater asthma morbidity and have higher asthma-related mortality rates.[2] The relationship between air pollution (eg, fine particulate matter [$PM_{2.5}$] and black carbon [BC]) and asthma morbidity in children is well established.[3,4] Local and regional traffic pollution are important sources of $PM_{2.5}$ and BC, which can penetrate indoors and contribute to poor indoor air quality.

In contrast to homes, schools have fewer indoor sources of pollutants, because most schools no longer have active kitchens and smoking is prohibited. However, traffic emissions are an important source, because schools are often centrally located within a community and consequently are closer to heavy traffic routes. In addition, there are many idling cars and buses for pick-up and drop-off. Indoor classroom pollutant exposures may be an important risk factor for asthma morbidity in children[5] because children spend a large portion of their day in school.

Previous studies of home-based environmental interventions using air cleaners have resulted in reduced particulate pollutant exposures and improved asthma symptoms in children.[6,7] Much less is known about the potential role of classroom-based interventions in improving air quality and asthma morbidity for children. In this study, our primary goal was to pilot the effect of an air cleaner intervention to reduce indoor particulate pollutants in classrooms of children with asthma. Our secondary goal was to determine the effect of reduced pollutant levels on asthma morbidity.

METHODS

Study population

We recruited 25 children with asthma, aged 6 to 10 years, from 18 unique classrooms in 3 urban elementary schools in the north-eastern United States from 2013 to 2014 (see flow diagram in Figure E1 in this article's Online Repository at www.jaci-inpractice.org). Inclusion and exclusion criteria used in other urban studies were adapted for this study as previously described.[8] Inclusion criteria included physician-diagnosed asthma for at least 1 year and at least 1 of the following: current daily preventative asthma medication, wheezing in the past year, or an unscheduled medical visit for asthma in the past year. Exclusion criteria included lung disease other than asthma, cardiovascular disease, beta blocker use, and enrollment in another asthma or allergy clinical trial. The study was approved by the local institutional review board and the participating school system. Informed consent was obtained from each participant's parent or legal guardian, and assent was obtained from each participant.

Study recruitment and baseline study visit

Validated screening survey questionnaires[8] were distributed in the spring of 2013 to the parents of students to determine eligibility for enrollment (see Figure 1 for study overview). During the summer of 2013, 25 students were enrolled and completed a baseline clinical assessment. This included a baseline demographic, medical, and symptom survey as well as spirometry performed according to American Thoracic Society guidelines[9] (Koko spirometer, Louisville, Colo).

Follow-up questionnaires and school visits

Follow-up asthma symptom surveys were performed through phone interviews at 3, 6, 9, and 12 months after the baseline visit. Follow-up spirometry was conducted in the fall and spring during school visits.

Exposure assessment

Environmental exposure assessment for indoor $PM_{2.5}$, BC, and settled dust allergen levels was completed at baseline before randomization and twice during the academic year (once in the winter and once in the spring). Air sampling for $PM_{2.5}$ and BC concentration was performed by placing personal exposure monitors 1.5 m above the floor in each classroom for 1 week, as far away from the air cleaner exhaust as possible. Sampling devices were set to an automatic timer that turned off after school and turned on when school started to restrict measurements to school hours. Each personal exposure monitor includes an inertial impactor (H-PEM, BGI Inc, Waltham, Mass)[10] to collect $PM_{2.5}$ on 37-mm Teflon membrane filters at a flowrate of 1.8 L/min. The Teflon filters were weighed before and after sample collection on an electronic microbalance (MT-5 Mettler Toledo, Columbus, Ohio). Indoor BC concentrations were measured by the reflectance method on the collected Teflon filters using a smoke stain reflectometer (model EEL M43D, Diffusion Systems Ltd, London, United Kingdom).

Classroom settled dust samples were collected using a hand-held vacuum with a special dust collector (DACI Lab, Johns Hopkins, Baltimore, Md) using a standardized protocol.[11] For each sample, standardized vacuum sampling was performed for 3 minutes on the floor and 3 minutes on desk/chair surfaces. Dust samples were analyzed using a multiplex array for indoor allergens (MARIA, Indoor Biotechnologies, Charlottesville, Va)[12] that simultaneously measured the following allergens: cockroach (Bla g 2), cat (Fel d 1), dog (Can f 1), mouse (Mus m 1), and dust mite (Der f 1).

Intervention

Eighteen classrooms (for the 25 participants) were randomized in a 1:1 ratio by school to receive high efficiency particulate air (HEPA) cleaners. This resulted in 9 intervention classrooms with 12 children and 9 control classrooms with 13 children. We used a commercial air cleaner (AP-1013A, Coway, Seoul, Korea) with a HEPA filter. A total of 4 air cleaners were placed on the floor in each intervention classroom in the same position throughout the study period: near the hallway, next to windows, and front and back of the classroom. To achieve a minimal impact on classroom activities, each air cleaner was adjusted to a noise level of 50 dB, corresponding to an air delivery rate of 3.7 m^3/min. For the control group, sham air cleaners were constructed by removing the filters and adding a sound