Being overweight increases susceptibility to indoor pollutants among urban children with asthma

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Background: Both being overweight and exposure to indoor pollutants, which have been associated with worse health of asthmatic patients, are common in urban minority populations. Whether being overweight is a risk factor for the effects of indoor pollutant exposure on asthma health is unknown.

Objectives: We sought to examine the effect of weight on the relationship between indoor pollutant exposure and asthma health in urban minority children.

Methods: One hundred forty-eight children (age, 5-17 years) with persistent asthma were followed for 1 year. Asthma symptoms, health care use, lung function, pulmonary inflammation, and indoor pollutants were assessed every 3 months. Weight category was based on body mass index percentile.

Results: Participants were predominantly African American (91%) and had public health insurance (85%). Four percent were underweight, 52% were normal weight, 16% were overweight, and 28% were obese. Overweight or obese participants had more symptoms associated with exposure to fine particulate matter measuring less than 2.5 μm in diameter ($PM_{2.5}$) than normal-weight participants across a range of asthma symptoms. Overweight or obese participants also had more asthma symptoms associated with nitrogen dioxide (NO_2) exposure than normal-weight participants, although this was not observed across all types of asthma symptoms. Weight did not affect the relationship between exposure to coarse particulate matter measuring between 2.5 and 10 μm in diameter and asthma symptoms. Relationships between indoor pollutant exposure and health care use, lung function, or pulmonary inflammation did not differ by weight.

Conclusion: Being overweight or obese can increase susceptibility to indoor $PM_{2.5}$ and NO_2 in urban children with asthma. Interventions aimed at weight loss might reduce asthma symptom responses to $PM_{2.5}$ and NO_2, and interventions aimed at reducing indoor pollutant levels might be particularly beneficial in overweight children. (J Allergy Clin Immunol 2013;131:1017-23.)

Key words: *Asthma, overweight, obesity, indoor pollutants childhood asthma, inner-city asthma*

The prevalence of both asthma and overweight status has increased dramatically over the past 20 years, suggesting that these 2 conditions might be linked.[1,2] In addition, African Americans, who have greater asthma morbidity than other racial/ethnic groups, also have a higher prevalence of being overweight or obese.[1,2] Several recent studies suggest that being overweight is a risk factor for both having a diagnosis of asthma and asthma morbidity.[3-7] Although relationships between being overweight and asthma have been examined in adult asthmatic populations, there are less data in children, particularly in high-risk populations, such as urban minority children, who might be most affected by both being overweight and having asthma.

A few studies suggest that the association between being overweight and asthma morbidity might be explained, in part, by resistance to the treatment effects of corticosteroids.[8,9] However, being overweight might confer susceptibility to worse asthma health through mechanisms other than corticosteroid resistance. For example, being overweight is associated with an underlying state of oxidative stress and inflammation, potentially reducing the capacity to defend against oxidative and proinflammatory exposures, such as particulate and gaseous pollutants.[10,11] In addition, fine-particle deposition in the lungs is greater in overweight children, so that lung exposure to a given airborne particulate matter concentration is greater in overweight children than in normal-weight children.[12]

Because fine particulate matter measuring less than 2.5 μm in diameter ($PM_{2.5}$), coarse particulate matter measuring between 2.5 and 10 μm in diameter ($PM_{2.5-10}$), and nitrogen dioxide (NO_2) are all associated with respiratory symptoms and rescue medication use in asthmatic patients,[13-19] it is plausible that the combination of a high prevalence of overweight status and higher indoor pollutant exposure among urban minority populations contributes to the disproportionate asthma morbidity in this population. We therefore hypothesized that overweight and obese urban children and adolescents with asthma are more susceptible

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Supported by the National Institute of Environmental Health Sciences (P50ES015903, P01ES018176), the Environmental Protection Agency (R832139), the National Institute of Allergy and Infectious Diseases (R01AI070630), and the Johns Hopkins University School of Medicine General Clinical Research Center (grant no. M01-RR00052) from the National Center for Research Resources/National Institutes of Health.

Disclosure of potential conflict of interest: P. N. Breysse has received a grant from the National Institutes of Health (NIH). G. B. Diette has received grants from the NIH, the National Institute of Environmental Health Sciences (NIEHS), and the US Environmental Protection Agency and has consultant arrangements with GlaxoSmithKline and Fenzian. R. D. Peng has received grants from the NIH and receives royalties from Springer Publishing. M. C. McCormack has received a grant from the NIEHS and has consultant arrangements with Alexza Pharmaceuticals. E. C. Matsui has received a grant from the NIH and received the Phadia Research Foundation Award. The rest of the authors declare that they have no relevant conflicts of interest.

Received for publication June 5, 2012; revised December 4, 2012; accepted for publication December 10, 2012.

Available online February 10, 2013.

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0091-6749/$36.00

http://dx.doi.org/10.1016/j.jaci.2012.12.1570

Abbreviations used
- BMI: Body mass index
- FENO: Fraction of exhaled nitric oxide
- IQR: Interquartile range
- NO_2: Nitrogen dioxide
- $PM_{2.5}$: Fine particulate matter measuring less than 2.5 μm in diameter
- $PM_{2.5-10}$: Coarse particulate matter measuring between 2.5 and 10 μm in diameter

to the effects of indoor pollutants than their normal-weight counterparts. To test our hypothesis, we examined relationships among weight status, asthma health, and indoor pollution in a population of urban, predominantly African American, asthmatic 5- to 17-year-olds.

METHODS

Study design and population

Relationships between weight status, asthma, and indoor pollution were examined in an institutional review board–approved prospective cohort study of 150 Baltimore City children and adolescents followed for 1 year. The participants were as follows: aged 5 to 17 years at enrollment, met National Asthma Education and Prevention Program criteria for persistent asthma or had been prescribed a controller medication, had an exacerbation in the previous 12 months, and were nonsmokers. Written consent was obtained from parents/guardians of participants, and assent was obtained from participants. Study visits occurred at baseline and 3, 6, 9, and 12 months, and nonpregnant participants with at least 1 valid height and weight measurement were included, resulting in a sample size of 148 children.

Study visit procedures

Skin prick testing was performed to 14 allergens at the baseline visit by using the MultiTest II device (Lincoln Diagnostics, Decatur, Ill), with a positive histamine control and a negative glycerol control. The allergens tested were as follows: dog, cat, *Dermataphagoides pteronyssinus*, *Dermataphagoides farinae*, rat epithelia, German cockroach, American cockroach, mouse epithelia, oak, grass mix, *Alternaria* species, *Aspergillus* species, common ragweed, and *Cladosporium* species (Greer Laboratories, Lenoir, NC). A positive skin test response was defined as a net orthogonal wheal size of 3 mm or larger than that elicited by the negative control. Atopy was defined as 1 or more positive skin test responses. Blood was collected at the baseline visit for measurement of total IgE levels. Total IgE levels were measured by using the ImmunoCAP system (Pharmacia Diagnostics, Uppsala, Sweden). Spirometry was performed at all study visits with a Koko spirometer, according to American Thoracic Society standards.[20,21] Fraction of exhaled nitric oxide (FENO) values were measured at all study visits with the Niox MINO (Aerocrine, Uppsala, Sweden), according to the manufacturer's instruction and American Thoracic Society standards.[22]

Questionnaires administered by study staff captured demographic information, pulmonary and allergic history, medications, symptoms, and asthma-related health care use. Medications were brought to clinic visits by study participants. Controller medication use was defined as use of any controller medication within the past 2 weeks before a visit. Asthma-related health care use included hospitalizations, emergency department visits, and unscheduled doctor's office visits. An acute care visit was defined as any hospitalization, emergency department visit, or unscheduled doctor's office visit. A "maximum symptom days" variable, as has been used in other inner-city asthma studies, was constructed by taking the maximum of the following symptom variables: days of slowed activity, days of wheezing, coughing or chest tightness when running or going upstairs, and nights of waking with asthma symptoms in the previous 2 weeks.[23]

TABLE I. Baseline sociodemographic characteristics (n = 148)

Age (y), median (range)	11.2 (5.0-17.8)
Male sex, no. (%)	85 (57)
Black/African American, no. (%)	135 (91)
Household annual income <$30,000 no. (%)*	86 (64)
Primary caregiver educational attainment, no. (%)	
Less than high school	42 (28)
High school graduate	51 (34)
Some college or more	55 (37)
Public health insurance, no. (%)	126 (85)
Households with smokers, no. (%)	84 (57)

*n = 134.

TABLE II. Baseline clinical characteristics (n= 148)

Allergic characteristics	No. (%)
Atopic (≥1 positive SPT response)*	134 (91)
Skin test sensitivities*	
Cat	96 (65)
Cockroach	91 (62)
Dust mite	85 (58)
Mouse	78 (53)
Dog	26 (18)
Total IgE (kU/L), median (IQR)†	190 (56-458)
Lung function	Mean ± SD
FVC (% predicted)‡	100.5 ± 14.9
FEV_1 (% predicted)‡	93.7 ± 17.9
FEV_1/FVC ratio‡	80.6 ± 9.6
FENO (ppb), median (IQR)§	33 (16-62)
Asthma-related health care use (12 mo before enrollment)	No. (%)
Hospitalization	29 (20)
Emergency department visit	121 (82)
Unscheduled doctor's office visit	61 (41)
Controller medication use	106 (72)
Days of short-acting β-agonist use/2 wk, mean ± SD	4.2 ± 5.0
BMI category	No. (%)
Underweight (<5th percentile)	6 (4)
Normal weight (5th-<85th percentile)	77 (52)
Overweight (85th-<95th percentile)	23 (16)
Obese (≥95th percentile)	42 (28)

FVC, Forced vital capacity; *SPT*, skin prick test.
*n = 147.
†n = 145.
‡n = 132.
§n = 131.

Height was measured in centimeters with a stadiometer. Weight was measured in kilograms. Body mass index (BMI) was calculated by using the following formula:

$$BMI = \text{weight in kilograms}/(\text{height in meters})^2.$$

BMI percentiles were calculated based on Centers for Disease Control and Prevention BMI for age growth charts for girls and boys.[24] Underweight was defined as a BMI of less than the 5th percentile, normal weight was defined as a BMI of the 5th to less than the 85th percentile, overweight was defined as a BMI of the 85th to less than the 95th percentile, and obesity was defined as a BMI of the 95th percentile or greater.

Home environment assessment

Airborne particulate matter monitoring was conducted in the child's bedroom by using integrated sampling methods for an approximately 5- to 7-day period. Air samples for measurement of both particulate matter of 10 μm or less (PM_{10}) and $PM_{2.5}$ were collected on Teflon filters (Pall Gelman, Ann Arbor, Mich) by using SKC Personal Environmental Monitors (SKC, Eighty-four, Pa) and BGI 400S pumps (BGI, Waltham, Mass).[25] Coarse