Environmental tobacco smoke exposure and nocturnal symptoms among inner-city children with asthma

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Background: Environmental tobacco smoke (ETS) is a frequent exposure and is linked to asthma among inner-city children.
Objective: We sought to examine the relationship among ETS exposure, select asthma symptoms, and consequences among inner-city children with asthma.
Methods: Data from interviews with primary caregivers of inner-city elementary school children with asthma were evaluated (n = 590). Caregiver reports of child asthma symptoms, exercise limitations, asthma management, health care use, and ETS exposure were examined.
Results: Smoking in the home was reported by 29.4% of primary caregivers. ETS exposure (yes/no) was not related to frequency of child nocturnal symptoms or other select asthma morbidity markers. However, among children exposed to ETS, the frequency and severity of child nocturnal symptoms were highest among children exposed to moderate-to-heavy levels of ETS. After controlling for child age, anti-inflammatory medication use, asthma primary care, and caregiver's education, exposure to higher levels of ETS was associated with nearly a 3-fold increase in nocturnal symptoms in children (odds ratio, 2.83; 95% CI, 1.22-6.55).
Conclusion: Among elementary school inner-city children with asthma, exposure to higher levels of ETS was associated with increased frequency of nocturnal symptoms. Reducing the exposure of children with asthma to ETS should be a clear priority in developing effective asthma management plans for inner-city families. (J Allergy Clin Immunol 2002;110:147-53.)

Key words: *ETS, asthma, inner city, children, asthma symptoms*

Pediatric asthma is a significant public health problem. Up to 26,000 new asthma cases arise in children each year.[1] Approximately 17% of all pediatric emergency department visits in the United States are attributable to asthma.[1] The Centers for Disease Control and Prevention reported that the asthma mortality rate nearly doubled from 1980 to 1993 among children aged 5 to 15 years and that black children were 6 times more likely than white children to die from asthma.[2] Prior studies have suggested that low-income minority children have disproportionately high rates of morbidity and mortality caused by asthma.[3,4] Disparity of asthma mortality and morbidity among minority inner-city children is closely linked to socioeconomic status, poverty, and environmental exposures.[5]

Abbreviation used
ETS: Environmental tobacco smoke

Environmental tobacco smoke (ETS) is a frequent indoor exposure that has been linked to asthma in children. Nearly 2 of 5 children aged 2 months to 2 years live with at least one smoker[6] and might have their condition made worse by exposure to ETS. ETS exposure is a risk factor for the development of asthma[1] and has been linked to increased frequency of lower respiratory tract illnesses in childhood,[7] increased respiratory symptoms and illness in children (ie, cough, phlegm, and wheeze),[8] asthma exacerbations,[8] and decrease in lung function.[9-11] It is estimated that ETS accounts for between 150,000 and 300,000 lower respiratory tract infections in infants and children under 18 months of age annually, resulting in between 7500 and 15,000 hospitalizations each year.[1]

Exposure to ETS might be far more ubiquitous than that reported in self-report interviews. Data from the Third National Health and Nutrition Examination Survey from 1988 to 1991 showed that 87.9% of nontobacco users in the United States had detectable levels of serum cotinine, a metabolite of nicotine.[12] Among inner-city families, ETS exposure is especially problematic. One study that assessed ETS exposure among urban low-income children seen in a pediatric resident practice reported that 75% of the children studied lived in a home with a smoker.[13] Another study of inner-city children in Baltimore, Maryland, reported that 80% of the children in this study had cotinine values of 30 ng/mg or greater, a level commonly associated with household ETS.[14] Up to one third of low-income children who do not live with a smoker spend time in a place with smokers.[13]

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Supported by grants HL 5201304 and HL 5283303 from the National Heart, Lung, and Blood Institute of the National Institutes of Health.
Received for publication October 23, 2001; revised April 15, 2002; accepted for publication April 19, 2002.
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0091-6749/2002 $35.00 + 0 **1/81/125832**
doi:10.1067/mai.2002.125832

We hypothesized, among inner-city elementary children with asthma, that those with ETS exposure at home would have higher rates of select markers of asthma morbidity, including nocturnal symptoms, daytime activity limitations, and missed school days in a dose-response fashion compared with the children without home ETS exposure.

METHODS

This study examined data collected from 2 identical baseline surveys designed to evaluate and improve asthma management among inner-city children and their families. In the first study, 24 inner-city elementary schools from Baltimore, Maryland, and 31 inner-city schools from Washington, DC, were invited to participate. In the second study 32 additional inner-city elementary schools in Baltimore were contacted. The surveys were conducted between October 1996 and September 1997 and were approved by the Joint Committee on Clinical Investigation of the Johns Hopkins University School of Medicine and the Howard University College of Medicine, Washington, DC. Details of recruitment, sample characteristics, and study design have been presented previously.[15,16]

Participants

Participants were the caregivers of eligible children in kindergarten to grade 5 who had an asthma diagnosis listed on their health records. Children were eligible for the study if their mothers reported that the child had (1) asthma diagnosed by a physician; (2) day or night symptoms, including wheezing, shortness of breath, cough, or some combination thereof at least once a week during the past 2 weeks; and/or (3) at least one visit for asthma to the emergency department in the previous 6 months or one admission to a hospital for asthma in the previous year. Data analysis included 678 participants who were enrolled in both studies. Of these, complete data on nocturnal symptoms and caregiver smoking were available on 590 children.

Data collection

Parents or guardians were mailed consent forms. After obtaining informed consent and child assent, trained interviewers who were blinded to the study purpose and hypotheses conducted a 30-minute phone interview with the individual identified as the primary caregiver at the time of enrollment in the study. Telephone surveys have been shown to provide reliable information on health status and behaviors.[17] The survey included 170 questions that assessed general sociodemographic information, environmental exposures, frequency of asthma symptoms, health care use, access to care, and asthma management practices.

Home ETS exposure was assessed by asking the following questions:

1. Does anyone who lives in your home smoke cigarettes?
2. If yes, how many people smoke inside your home?
3. Do you smoke cigarettes?
4. On average, how many cigarettes do you smoke a day?
5. Do you smoke cigarettes inside your home?

The first question was used to identify ETS-free status; if no one who lived in the home smoked (including the caregiver), the home was classified as "ETS absent." If the caregivers reported that they smoked cigarettes (question 3) in their home (question 5), the homes were classified as "ETS present." Willers et al[18] recently used the same sequence of questions to assess ETS home exposure among young urban children and reported that question 5 (ie, Do you smoke cigarettes inside your home?) was the best predictor of child cotinine levels. To reduce misclassification, caregivers who reported that they smoked but not in their homes were dropped from subsequent analyses.

Outcome measures

The primary outcome measure was the number of nights per month that the child awoke during the night with asthma-related symptoms. Caregivers were asked to estimate, on average, the number of nights per week (or month) that their children awakened at night with cough, wheeze, shortness of breath, or tightness in the chest. The frequency of nighttime symptoms was classified by using the National Asthma Education and Prevention Program guidelines. Mild intermittent asthma included nocturnal symptoms 2 or fewer times a month. Mild persistent asthma included nocturnal symptoms more than 2 times a month and 4 or fewer times a month (or once a week). Moderate-to-severe persistent asthma was defined as having nocturnal symptoms more than 4 times a month.

Caregivers were asked to estimate, on average, how many days per week (or month) that cough, wheeze, or shortness of breath limited the child's exercise or ability to play sports or play with friends. Limited activity as a result of asthma was dichotomized (yes limited activity/no limited activity). Caregivers also estimated the number of days of school the child had missed in the past year because of asthma. They were also asked to estimate the number of days of work they or another member of the family missed in the past 6 months because of their child's asthma.

Statistical analyses

In this study we wished to evaluate whether home ETS exposure was associated with several indices of asthma morbidity in inner-city children with asthma. χ^2 Analyses and *t* tests were used to examine the differences in the sociodemographic characteristics of children in homes with and without ETS. Among those children with home ETS exposure (ie, caregiver reported smoking in the home), the association between dose and child's asthma morbidity was further examined by classifying exposure as moderate to high (ie, ≥10 cigarettes per day) or low (ie, 1-9 cigarettes equivalent to one-half pack per day). Logistic regression was used to estimate crude and adjusted odds ratios for the presence of nocturnal symptoms (controlling for the effects of child age, exposure level, caregiver education, presence of asthma primary care, and use of anti-inflammatory medications). Candidate predictor variables were chosen on the basis of empiric studies and significance in the univariate analyses. SPSS (version 10.0.7) was used to analyze the data.

RESULTS

Demographic, health care, and environmental characteristics

The majority of the children in our study were African American (98%) and female (60%), with a mean age of 8.2 ± 2.0 years. The child's mother was the caregiver 89% of the time, a family relative 6% of the time, or the child's father 2% of the time. The mean age of the caregivers was 34.7 ± 8.1 years. Ninety percent of the families reported that they had health plans that covered all or part of the cost of prescription medications, and 93% reported having medical assistance or insurance that paid for all or part of their health care. Similarly, most reported having no problem paying for asthma medication (89%), a doctor's visit (91%), or an emergency department visit (87%). On average, children visited their doctor for regular asthma care 3.3 ± 5.2 times in the past year.

As shown in Fig 1, of 590 caregivers queried, 367 reported that no one in the home smoked (ie, ETS absent). Of the 233 caregivers who reported that some-

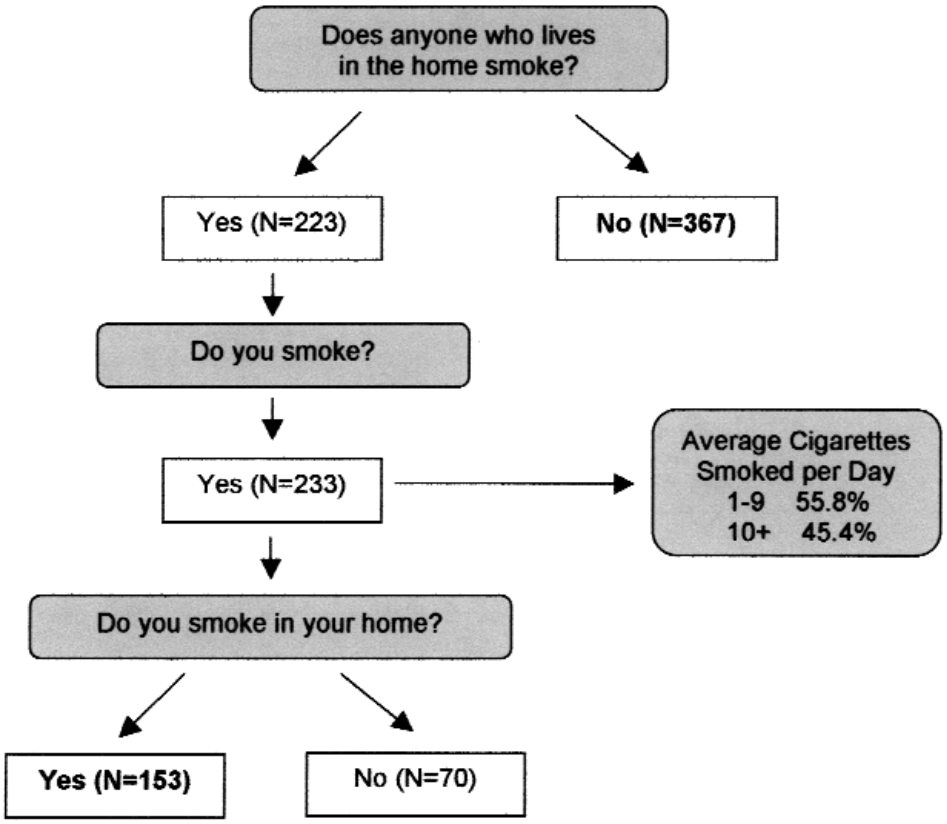

FIG 1. Home ETS exposure classification.

one living in the home smoked, the average number of smokers in the house was 1.3 ± 0.6. A total of 233 caregivers reported that they smoked, on average, 9 ± 9 cigarettes per day. Among caregivers who smoked, 153 (65.7%) reported smoking in the home (ie, ETS present). As shown in Table I, caregivers who smoked in the home were less likely to have completed high school or further education, more likely to be poorer, and more likely to be unemployed. In contrast, however, there were large differences in caregiver education, family income, and employment status, especially at the lowest levels, potentially reflecting differences in socioeconomic status in homes with ETS exposure. Children exposed to ETS were also less likely to receive asthma primary care.

Asthma morbidity and smoking

Initial cross-sectional analyses were used to evaluate the relationship between ETS exposure (yes/no) and select asthma morbidity measures. As shown in Table II, there was no association between ETS exposure and severity of nocturnal symptoms, limitations in physical activity, or missed school days in children. Similarly, among parents who reported working full or part time, those with children exposed to ETS at home were not more likely to miss work because of the child's asthma.

Next, in homes with ETS exposure, we evaluated whether the level of exposure was associated with select asthma symptoms. Higher levels of ETS exposure (≥10 cigarettes per day) were associated with more severe nocturnal symptoms (Table III). Children with moderate-to-heavy ETS exposure (ie, caregivers smoking ≥10 cigarettes per day) were more than 3 times as likely to be in the mild persistent disease category and twice as likely to be in the moderate-to-severe disease category compared with those who were exposed to a lower level of ETS.

Predictors of the presence of nocturnal symptoms among children were also examined. As shown in Table IV, in homes with ETS exposure, children who were exposed to moderate-to-high levels of ETS were 2.8 times more likely to have nocturnal symptoms than children exposed to low levels of ETS. Use of daily or as-required anti-inflammatory medications was associated with a greater likelihood of having nocturnal symptoms. In the adjusted model (ie, controlling for child age, caregiver education, primary asthma care, and use of anti-inflammatory medications), children with moderate-to-high ETS exposure were still 2.8 times more likely to have nocturnal symptoms.

TABLE I. Sociodemographic and health care characteristics for children with asthma by ETS exposure status

	n	ETS exposure		*P* value
		Present (n = 153)	Absent* (n = 367)	
Child age (y)	520	8.3 ± 2.2	8.2 ± 2.0	.413
Child sex (% male)	520	39.9	41.1	.787
Caregiver age (y)†	498	35.8 ± 7.1	34.3 ± 8.2	.052
Caregiver education‡ (%)				
<High school/GED	132	41.2	18.9	<.001
Completed high school/GED	252	42.5	51.1	
>High school/GED	135	16.3	30.1	
No. of persons living in house	520	4.5 ± 1.8	4.3 ± 1.7	.395
Annual family income§ (%)				
<$10,000	219	55.7	38.6	.001
$10,000-$20,000	126	20.8	27.0	
>$20,000	156	23.5	34.4	
Caregiver employment status‡ (%)				
Not working outside home	225	56.2	38.0	<.001
Part time	74	11.8	15.3	
Full time	220	32.0	46.7	
Problems paying for asthma care (%)				
Asthma medicines	508	10.1	11.7	.597
Provider visits	518	10.5	8.5	.479
Emergency department use (%)	514	12.0	13.5	.655
Transportation	518	33.3	21.6	.008
Has primary care for asthma‡ (%)	519	88.9	84.2	.162

Values are given as means ± SD where shown.
*As defined by maternal reports of smoking behavior in the home, a measure that has been shown to be the best predictor of child biomarkers.
†One hundred forty-seven subjects were exposed, and 351 were unexposed.
‡One hundred fifty-three subjects were exposed, and 366 were unexposed.
§One hundred forty-nine subjects were exposed, and 352 were unexposed.

TABLE II. Reports of child's asthma symptoms and consequences by ETS exposure status

	n	ETS exposure		*P* value
		Present (n = 153)	Absent* (n = 367)	
Nocturnal symptoms (mo)				
Mild intermittent (≤2 nights)	126	43 (28.1%)	83 (22.7%)	.251
Mild persistent (2-4 nights)	100	32 (20.9%)	68 (18.6%)	
Moderate-severe (≥5 nights)	293	78 (51.0%)	215 (58.7%)	
Limited physical activity in past 6 mo‡				
Yes	335	92 (60.1%)	243 (66.9%)	.139
No	181	61 (34.8%)	120 (33.1%)	
Days of work missed in past 6 mo because of child's asthma†	291	3.3 ± 12.0	3.5 ± 5.4	.820
School days missed by child because of asthma§	515	7.2 ± 10.4	6.7 ± 9.0	.589

Values are given as means ± SD where shown.
*As defined by reports of maternal smoking behavior in the home, a measure that has been shown to be the best predictor of child biomarkers.
†Caregiver or other family member who missed work to care for child with asthma. Analyses restricted to only those caregivers reporting full- or part-time employment (n = 66 exposed and n = 225 unexposed).
‡One hundred fifty-three subjects were exposed, and 363 were unexposed.
§One hundred fifty-two subjects were exposed, and 363 were unexposed.

DISCUSSION

The primary finding of this study was that caregivers of children with asthma who were exposed to moderate-to-high levels of ETS were more likely to report frequent nocturnal symptoms than those exposed to low levels. Even after controlling for potentially confounding factors, such as child age, caregiver education, and asthma care and management (ie, use of anti-inflammatory medications), in homes with ETS exposure, children with moderate-to-high exposure levels were nearly 3 times as likely to awaken at night because of nocturnal asthma symptoms. In this study a threshold of one-half pack per day (ie, 10 cigarettes; equivalent to light smoking) corresponded to the level of environmental irritants at which children with asthma experienced nocturnal symptoms.

TABLE III. Relationship between exposure level, nocturnal symptoms, and consequences in children with home ETS exposure (n = 153)

		ETS exposure level			
	n	Moderate-high* (n = 71)	Low (n = 82)	Odds ratio (95% CI)	*P* value
Nocturnal symptoms (mo)					
Mild intermittent (≤2 nights)	43	13 (18.3%)	30 (36.6%)	1	.027
Mild persistent (2-4 nights)	32	19 (26.8%)	13 (15.9%)	3.4 (1.3-8.8)	
Moderate-severe (≥5 nights)	78	39 (54.9%)	39 (47.6%)	2.3 (1.0-5.1)	
Limited physical activity past 6 mo					
Yes	92	48 (67.6%)	44 (53.7%)	1.80 (0.93-3.5)	.079
No	61	23 (32.4%)	38 (46.3%)	1	
Days of work missed in past 6 months because of asthma†	66	2.3 ± 3.0‡	3.9 ± 15.3		.478
School days missed	152	8.4 ± 10.9‡	6.2 ± 9.9		.204

Values are given as means ± SDs where shown.
*High exposure was defined as caregivers who reported smoking 10 or more cigarettes per day; low exposure was defined as 1 to 9 cigarettes per day.
†Caregiver or other family member who missed work to care for child with asthma. Analyses restricted to only those caregivers reporting full- or part-time employment (n = 26 with high exposure; n = 40 with low exposure).
‡Seventy subjects were in the exposed category.

TABLE IV. Crude and adjusted odds ratios and 95% CIs for presence of nocturnal symptoms among inner-city children with ETS exposure (n = 149)

	n	Crude odds ratio	95% CIs	Adjusted odds ratio*	95% CIs
Child age (y)	149	0.95	0.80-1.12	0.98	0.82-1.17
ETS exposure					
Low (<10 cigarettes/d)	80	1		1	
Moderate-high (≥10 cigarettes/d)	69	2.84	1.25-6.42	2.83	1.22-6.55
Caregiver education					
<High school	61	1		1	
≥High school	88	0.83	0.39-1.77	0.89	0.40-2.01
Has asthma primary care					
No	17	1		1	
Yes	132	0.64	0.17-2.38	0.51	0.13-1.97
Anti-inflammatory medications†					
No	115	1		1	
Yes	34	4.16	1.19-14.54	4.43	1.23-15.90

The reference group is indicated as 1.
*Adjusted model includes child age, ETS exposure level, caregiver education, asthma primary care, and use of daily or as-required anti-inflammatory medications in the full model.
†Includes use of daily or as-required chromolyn, inhaled steroids, or both in past 6 months.

To our knowledge, this is the first study to evaluate the relationship between nocturnal symptoms in inner-city children and ETS exposure. Nocturnal symptoms of asthma (eg, cough, wheeze, and shortness of breath) are markers of disease severity and activity that have been linked with decreased school attendance and performance and parent's work attendance.[19] According to the National Asthma Education and Prevention Program guidelines, the presence of nocturnal symptoms clearly defines disease severity and appropriate treatment.[20] Moderate persistent asthma (ie, symptoms more than once a week) requires initiating an anti-inflammatory medication.[20]

The dose-response relationship that we observed between ETS exposure level and nocturnal symptoms suggests that nocturnal symptoms might be one of the symptoms that are more sensitive to the level of ETS exposure. The mechanisms through which ETS might exacerbate nocturnal symptoms are not clear. Acute exposure to ETS in the evening in adults with asthma results in a deterioration of airway tone and responsiveness during the night, with wide interindividual variability in the response.[21] In children parental smoking is associated with increase hyperresponsiveness,[22,23] which is evident even in young normal children.[24] Meijer et al[25] also noted that ETS exposure seemed to worsen peak expiratory flow variability in children with mild to moderately severe bronchial hyperresponsiveness. Others have theorized that there might be circadian variations in mast cell discharge that contributes to nocturnal symptoms.[26] Changes in circadian rhythm might explain why

nocturnal symptoms might be sensitive to changes in environmental exposures, such as ETS. Proposed mechanisms that have been implicated include interaction between a fall in circulating adrenaline, delayed effects of cortisol withdrawal, and increased vagal tone at night, which together result in increased bronchoconstriction.[27] An alternative explanation is that nocturnal asthma symptoms might be a late reaction to environmental exposures inhaled during the day.[27]

Our findings are consistent with those of previous reports that have found an association between caregiver smoking and asthma morbidity in children. Current maternal smoking has been linked with reports of wheezing in young children.[28] Martinez et al[28,29] also reported that children of mothers who smoked 10 or more cigarettes per day were likely to have wheezing and asthma. Diette et al[19] have reported that nocturnal asthma was related to school attendance and performance in children and work attendance in their parents in a cohort of children enrolled in 3 large managed care organizations.

The relationship between ETS exposure and asthma is unclear.[30] In this study nocturnal symptoms did not differ between children who were and were not exposed to ETS at home. This unexpected finding might reflect confounding by indication where caregivers of children with severe asthma have already eliminated or reduced home ETS exposure. For example, others have found that some caregivers of children with severe asthma chose to quit because of their child's asthma severity.[18] Given the cross-sectional nature of this study, we were unable to determine whether nonsmokers were never smokers or in fact exsmokers. In addition, we did not consider ETS exposure from other sources in this study. Older children spend less time with their parents, and noncaregiver exposure to ETS outside the home might be increasingly important as the child ages.[31] We did not query the smoking habits of children in the study; estimates suggest that up to 10% of third graders and 18% to 24% of fifth graders have tried smoking.[32]

This study relied on self-reports of smoking behaviors of caregivers and asthma morbidity obtained through telephone interviews. Underreporting might have been a factor. Caregivers who had been advised by their child's health care provider to stop smoking might have been more reluctant to be forthright about cigarette smoking. However, self-reports of ETS exposure can be considered to be a useful indicator of being exposed, although the validity of reports of intensity of exposure is less certain.[33] Parent reports of asthma symptoms have been previously shown to have good concurrent validity with other standard measures of asthma morbidity in this population.[34,35] Others have reported that telephone interviews provide reliable estimates of health behaviors.[17]

In summary, among inner-city children with asthma, exposure to moderate-to-heavy ETS was associated with increased frequency of nocturnal symptoms. Reducing the exposure of children with asthma to ETS should be a clear priority in developing effective asthma management plans for inner-city families.

We thank Drs Jodi Segal, Jerry Krishnan, and Gregory Diette for their helpful comments on earlier drafts of this manuscript.

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