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Factors associated with high short-acting β_2 -agonist use in urban children with asthma

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ABSTRACT

Background: One goal of guideline-based asthma therapy is minimal use of short-acting β_2 agonist (SABA) medications. Inner-city children with asthma are known to have high SABA use.

Objective: To examine factors associated with high SABA use in inner-city children with asthma.

Methods: One hundred inner-city children with persistent asthma were enrolled into a randomized controlled trial of an emergency department (ED) and home intervention. All children underwent serologic allergen specific IgE and salivary cotinine testing at the ED enrollment visit. Pharmacy records for the past 12 months were obtained. Number of SABA fills during the past 12 months was categorized into low- to moderate- vs high-use groups. SABA groups were compared by the number of symptom days and nights, allergen sensitization, and exposures. Regression models were used to predict high SABA use.

Results: Mean number of SABA fills over 12 months was 3.12. Unadjusted bivariate analysis showed that high SABA users were more than 5 times more likely to have an asthma hospitalization, almost 3 times more likely to have an asthma intensive care unit admission, and more than 3 times more likely to have prior specialty asthma care or positive cockroach sensitization than low to moderate SABA users. In the final regression model, for every additional inhaled corticosteroid fill, a child was 1.4 times more likely and a child with positive cockroach sensitization was almost 7 times more likely to have high SABA use when controlling for prior intensive care unit admission, receipt of specialty care, child age, and income.

Conclusion: Providers should closely monitor SABA and controller medication use, allergen sensitization, and exposures in children with persistent asthma.

Trial registration: ClinicalTrials.gov, identifier NCT01981564.

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Introduction

An estimated 7.1 million US children have asthma, with African-American children showing higher asthma morbidity and a 7.6 times higher mortality rate than non-Hispanic white children.^{1,2} Although causes for the increased morbidity and mortality are multifold, inappropriate use of asthma medications has been reported as a major contributor to uncontrolled asthma in inner-city populations.^{3,4} Although the elevated rates of asthma morbidity and mortality experienced by minority inner-city children are widely known, these children have increased odds of overusing short-acting β_2 -agonist (SABA) on a daily basis³ and are the least likely to receive adequate guideline-based therapy^{5–7} or specialty care for asthma.^{8–10} Frequent use of SABA medication is a key

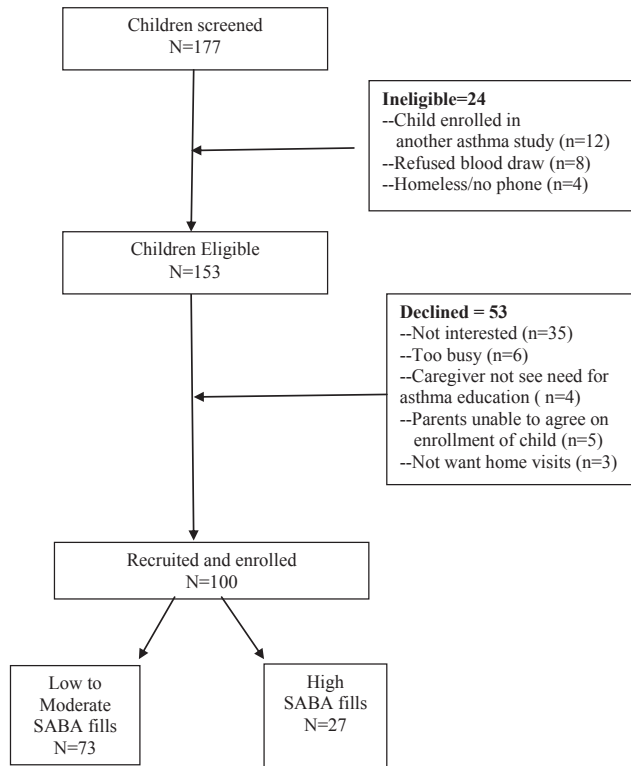


Figure 1. Recruitment flow diagram. SABA, short-acting β -agonist.

indicator of poor asthma control.^{5,11–14} Use of at least 3 SABA canisters per year by children with asthma has been associated with a 2-fold increase in the risk of asthma-related hospitalization or emergency department (ED) visits.¹⁵

Several explanations for increased SABA use by inner-city children have been proposed. Allergen sensitization and exposure have been associated with increased asthma morbidity and SABA use.¹⁶ Multiple allergen sensitization and exposure can result in greater adverse effects than sensitization and exposure to a single allergen.¹⁷ The type of housing available to families of inner-city children with asthma have high levels of multiple environmental allergens, such as mouse, cockroach, cat, mold, and dust mite.¹⁸ Exposure to these major allergens can result in an increased risk for allergen sensitization, recurrent wheezing,¹⁹ and increased ED visits and hospitalizations.²⁰ In addition, low-income inner-city children are more frequently exposed to second-hand smoke (SHS) than non-poor children.^{10,21–23} Indoor SHS exposure, particularly maternal smoking, has been associated with a 52% increased risk of wheeze and a 20% increased risk of asthma at 5 to 18 years of age,²⁴ and any home SHS exposure has been associated with increased asthma symptoms.²⁵ Identifying factors associated with frequent SABA medication use, indicative of poor asthma control, including allergen sensitization and indoor exposures to allergens and SHS, could be helpful in targeting individualized environmental control and community-level asthma interventions for inner-city families. Therefore, the objective of this study was to examine factors, including allergic sensitization and SHS exposure, associated with high SABA use by low-income inner-city children with frequent ED visits for asthma.

Methods

Study Design and Population

This report presents a sub-analysis of baseline data from 100 participants enrolled in an ongoing randomized controlled trial

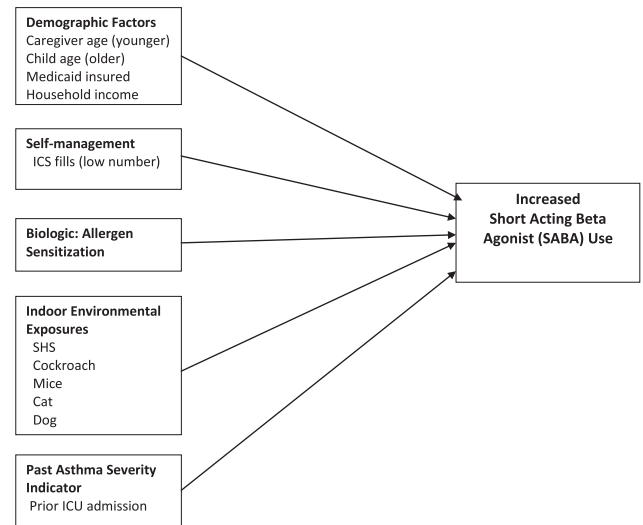


Figure 2. Conceptual model for factors associated with increased SABA use. ICS, inhaled corticosteroid; ICU, intensive care unit; SABA, short-acting β -agonist; SHS, second-hand smoke.

testing the effectiveness of an ED- and home-based environmental control intervention for children with frequent ED visits for asthma. One primary aim of the intervention was to increase controller medication use and decrease SABA use when indicated. The primary outcome of this sub-analysis was the level of SABA use over 12 months. The Johns Hopkins medical institutional review board (Baltimore, Maryland) approved the study protocol. Children were recruited, consented, and were enrolled during an ED visit for treatment of an acute asthma exacerbation (ED enrollment visit). Data were collected from August 2013 through October 2014. Inclusion criteria were physician-diagnosed persistent asthma and uncontrolled asthma based on current National Asthma Education Prevention Program guidelines,¹³ at least 2 ED asthma visits or at least 1 hospitalization for asthma during the past 12 months, age 3 to 12 years, and residence in the Baltimore metropolitan area. Children were excluded if they had significant other nonasthmatic respiratory conditions, such as cystic fibrosis, were enrolled in another asthma study, refused blood draw for a radioallergosorbent test (RAST), or were homeless and/or lacked access to a telephone for delivery of the home intervention. After screening 177 children with asthma in the ED, 153 children were eligible. Of the 153 eligible children, 100 met the inclusion criteria, agreed to participate, and were enrolled in the study (Fig 1). After written informed consent was obtained from each child's primary caregiver or legal guardian and verbal assent was obtained from children older than 8 years, children were randomly assigned to the ED-home based intervention or an attention control group in a 1:1 ratio. During the enrollment ED visit, all children received serologic allergen specific IgE testing (RAST) to assess sensitization to 10 common indoor and outdoor allergens and their saliva was collected to measure cotinine, a metabolite of nicotine, to determine their level of SHS exposure. The RAST and cotinine test results were sent to each child's primary care provider (PCP) and caregiver within 1 to 2 weeks after the enrollment ED visit as part of the ED and home environmental control intervention. Control PCPs and caregivers received the same information at the end of the 3-month control intervention period.

Measurement of Variables

The hypothesized factors associated with high SABA use by inner-city children with frequent ED visits for asthma and

examined in this analysis are shown in Figure 2. The model includes demographic factors (caregiver age and child age, Medicaid insurance, and household income), self-management (low use of inhaled corticosteroids [ICSs]), biologic or allergic sensitization factors, indoor environmental exposures (SHS, cockroach, mice, cat, and dog), and a prior intensive care unit (ICU) admission as an indicator of more severe asthma. The measurement of these variables is described below.

Frequency of SABA medication use

The primary outcome for this analysis was the frequency of SABA use during the 12 months before the enrollment ED visit and was based on pharmacy records. Pharmacy records of all asthma medications dispensed during the 12-month period before the baseline interview, including the dispensing date, product name, strength, dosage form, and quantity dispensed, were used as an objective measurement of asthma medication use. Pharmacy records were obtained from all pharmacies listed by the caregiver as being used during the 12-month baseline period. The number of SABA canisters, defined as SABA fills per 12 months, was examined across all participants, and high SABA use was defined as SABA fills in the top quartile ($>75\%$; ≥ 4 fills), with all others classified as low to moderate use. In addition, caregivers reported the number of days of SABA use during the prior 2 weeks.

Frequency of ICS fills as a proxy for caregiver self-management behavior

The number of ICS fills per 12 months, calculated from pharmacy record data, was selected as the measurement of anti-inflammatory exposure because ICSs were the most commonly filled controller medication. In addition, caregiver report of controller medication use and oral corticosteroid courses during the past 6 months were ascertained during the baseline survey.

Sociodemographic covariates

Surveys administered at baseline by face-to-face interview assessed demographic characteristics such as age, sex, and race of the child and age, relationship to the child, and educational status, employment status, and income level of the primary caregiver. Income level was categorized as \$0 to \$19,000, \$20,000 to \$39,000, and more than \$40,000 per year. Medicaid insurance status of the child also was ascertained at baseline.

Allergen sensitization: serologic allergen specific IgE test (RAST)

To perform the RAST, 6 mL of blood was obtained from the child during the ED enrollment visit and sent to a private laboratory for analysis. The RAST was performed using an immunoassay (ImmunoCap, Phadia AB, Uppsala, Sweden) childhood allergy profile that measures IgE antibodies for common allergens (mouse, cockroach, cat, dog, timothy grass, *Alternaria alternata*, *Aspergillus fumigatus*, oak tree, common ragweed, and *Dermatophagoides farina* [house dust mite]). The degree of sensitization ranged from lower than 0.35 to higher than 100 kU/L of specific IgE to any of the allergens tested.

Cotinine analysis for SHS exposure

Child saliva samples were collected during the index ED asthma visit. A 3-cm cotton swab (Salimetrics, State College, Pennsylvania) was placed under the child's tongue for 1 minute to absorb a minimum of 1 mL of saliva. The cotton roll was placed in a 2-mL vial and stored at -20°C before transport to the laboratory and then centrifuged and analyzed at the Johns Hopkins Institute for Clinical and Translational Research laboratory using enzyme immunoassay analysis. The cotinine analysis serves as a biomarker of nicotine exposure during the prior 24 hours. The lower limit of cotinine sensitivity was 0.05 ng/mL and average intra- and interassay coefficients of variation were lower than 5.8% and 7.9%, respectively. A cotinine cutoff level of 1.0 ng/mL was used to define positive SHS

exposure based on comparable samples of inner-city children with asthma.^{26,27}

Indoor environmental exposure assessment

Data on indoor exposure to cats, dogs, mice, rats, or cockroaches, the number of smokers in the home, the smoker's relationship to the child, and type of home smoking ban (total, partial or some restrictions, and no restrictions) were reported by the caregiver on the baseline questionnaire at the ED enrollment visit.

Asthma morbidity and health care usage

Asthma morbidity measurements included the number of symptom days and nights during the past 2 weeks based on current National Asthma Education Prevention Program guidelines.¹³ Caregivers were asked to rate their perception of the child's asthma control during the past 4 weeks as "controlled," "not controlled," or "unsure." Caregiver understanding of the child's asthma control was not ascertained. Health care usage measurements included the number of asthma ED visits, number hospitalizations for asthma, and number of PCP visits for routine asthma care reported during the past 3 months. Office urgent care visits for asthma were not included in the ED asthma visit counts to target high-cost usage. Caregiver report of any lifetime ICU admission for asthma, indicative of children at high risk for future life-threatening exacerbations, was confirmed with an electronic medical record review. High concordance (83% agreement) was found between the caregiver report and the electronic medical record for lifetime ICU admission.

Statistical Analysis

Standard frequencies were used to describe baseline demographic and health-related variables for all children. The primary outcome, the number of SABA fills during the past 12 months, was categorized as low to moderate use (first to third quartile of fills) or high use. High SABA use was defined as the upper quartile of SABA fills during 12 months (≥ 4 SABA fills during 12 months). Mean number of SABA fills during 12 months was 3.12 and higher than prior reports of SABA use in a comparable group of high-risk children with asthma after an ED asthma visit (mean 1.90 SABA canisters per 12 months).²⁸ Owing to the non-normal distribution of salivary cotinine concentrations, all cotinine values were transformed logarithmically for analysis as a continuous variable. To control for asthma seasonality, a season variable was created with the season based on the date of the ED enrollment visit. Unadjusted odds ratios were calculated using logistic regression for associations between high SABA use by child age, caregiver perception of asthma control, exposure to SHS and exposure to indoor allergens, season of enrollment ED visit, allergen sensitizations, and any prior ICU admission. The Student *t* test and analysis of variance were used to compare the 2 SABA groups by the continuous variables, including symptom days and nights, number of ED visits, and number of hospitalizations. Forward conditional stepwise multivariate logistic regression was used to predict high SABA use while adjusting for caregiver age and child age (categorized as 3–5 vs 6–12 years), child sex, income, number of ICS fills, cockroach allergy sensitization status, prior ICU asthma admission, receipt of asthma specialty care, and cotinine level (categorized as positive vs negative). Variable selection criteria for inclusion in the model were set at entry at a *P* value equal to .35 and variable exclusion criteria were set at a *P* value less than .30. Two-sided tests were used and *P* values less than or equal to .05 were considered statistically significant. All analyses were conducted using SPSS 22 (SPSS Inc, Chicago, Illinois).²⁹

Table 1

Baseline sociodemographic and health characteristics of sample (N = 100)

Child characteristics	
Age (y), mean (SD)	6.25 (2.6)
3–5	50 (50.0)
6–12	50 (50.0)
Sex, n (%)	
Boys	56 (56.0)
Girls	44 (44.0)
Race or ethnicity, n (%)	
African American	95 (95.0)
White	1 (1.0)
Other	4 (4.0)
Medical insurance (n = 99)	
Medicaid	96 (97.0)
Private insurance	3 (3.0)
No insurance	0 (0.0)
Caregiver characteristics	
Age (y), mean (SD)	31.8 (7.8)
Age range (y)	19–58
Relationship to child, n (%)	
Biological mother	93 (93.0)
Grandmother	4 (4.0)
Missing	3 (3.0)
Education (n = 91), n (%)	
<9th grade	2 (2.0)
Some HS	17 (17.0)
HS graduate or GED	38 (38.0)
At least some college	43 (43.0)
Marital status (n = 99), n (%)	
Single	76 (76.8)
Married	16 (16.2)
Divorced, separated, or widowed	6 (6.0)
Other	1 (1.0)
Employment status, n (%)	
Part time	13 (13.0)
Full time	43 (43.0)
Unemployed or other	44 (44.0)
Income (n = 99), n (%)	
<\$10,000	35 (35.4)
\$10,000–\$29,000	31 (31.3)
\$30,000–\$39,000	10 (10.1)
>\$40,000	14 (14.1)
Refused	9 (9.1)
Medication use characteristics	
SABA use (pharmacy fills during 12 mo)	
Mean (SD)	3.12 (2.8)
Range	0–18
High use (top quartile), range	4.25–18
ICS use (pharmacy fills during 12 mo)	
Mean (SD)	2.09 (2.9)
Range	0–16
Controller medication use in past 2 wk, n (%)	
Yes	77 (77.0)
No	23 (23.0)
Duration of SABA medication canister (n = 98), n (%)	
<1 mo	30 (30.6)
1–2 mo	47 (48.0)
≥3 mo	21 (21.4)
Duration of controller medication canister (n = 77), n (%)	
<1 mo	25 (32.5)
1–2 mo	46 (59.7)
≥3 mo	6 (7.8)
Number of oral steroid courses reported in past 3 mo, mean (SD)	3.04 (2.8)
Health care usage characteristics	
≥1 PCP visit for asthma in past 3 mo, n (%)	54 (54)
Received specialty care for asthma in past, n (%)	20 (20)
Number of asthma-related ED visits for asthma in past 3 mo, mean (SD)	1.37 (1.0)
Number of asthma-related hospitalizations in past 3 mo, mean (SD)	0.12 (0.4)
Had prior ICU admission (lifetime) as confirmed by medical record confirmed, n (%)	31 (31.0)
Asthma control in past 4 wk (caregiver report), n (%)	
Well controlled	51 (51.0)
Not well controlled	42 (42.0)
Unsure	7 (7.0)

(continued)

Table 1 (continued)

Allergen sensitization and exposure characteristics	
Positive allergy sensitization, n (%)	
Dog	56/92 (60.9)
Cat	52/92 (56.5)
Mouse	45/87 (51.7)
Cockroach	40/90 (44.4)
Timothy grass	39/92 (42.4)
<i>Dermatophagoides</i> spp	38/89 (42.7)
Oak tree	38/91 (41.8)
<i>Aspergillus fumigatus</i>	30/91 (33.0)
<i>Alternaria alternata</i>	31/91 (34.1)
Ragweed	29/92 (31.5)
Any positive allergy (yes), n (%)	73/91 (80.2)
Smokers in home, n (%)	
0	43 (43.0)
1	34 (34.0)
2	16 (16.0)
≥3	7 (7.0)
Mother is smoker (n = 57 smokers)	19/57 (33.3)
Cotinine transformed logarithmically, mean (SD)	0.13 (0.4)
Cotinine positive (≥1.0 ng/mL) (n = 98), n (%)	53 (54.1)
Rodents and roaches in home by self-report, n (%)	
Mice (yes)	50/100 (50.0)
Cockroaches (yes)	45/100 (45.0)
Rats (yes)	7/100 (7.0)
Pets in home by self-report, n (%)	
Dogs (yes)	18/99 (18.2)
Cats (yes)	30/99 (30.3)
Mice + cat in home (yes)	16/100 (16.0)

Abbreviations: ED, emergency department; GED, General Education Development; HS, high school; ICS, inhaled corticosteroid; ICU, intensive care unit; PCP, primary care provider; SABA, short-acting β_2 -agonist.

Results

Study Population

A demographic description of the study sample is presented in Table 1. Child participants were primarily African American (95%), boys (56%), and insured through Medicaid (97%) and had a mean age of 6.3 years (SD 2.6 years). Caregivers were predominantly the child's biological mother (93%). Most caregivers were single (77%), at least high school graduates (81%), employed (56%), and had a household income lower than \$30,000 (67%).

Children were highly atopic, with 80% sensitized to at least 1 allergen tested. The most common positive allergen sensitizations were to dog (61%), cat (57%), mouse (52%), and cockroach (44%). Older children (6–12 years old) had significantly higher rates of positive allergen sensitivity rates for all allergens except mouse, cat, and *Aspergillus* species compared with younger children (3–5 years old; Figure 3). Indoor exposure to allergens was high for mouse (50%), cockroach (45%), and cat (30%); concurrent cat and mouse exposure was reported in 16% of homes. Child age was not associated with indoor exposure to cat, dog, cockroach, or mouse. Exposure to SHS was high, with 54% of children having cotinine levels consistent with SHS exposure (>1.0 ng/mL of cotinine) and 57% of caregivers reporting at least 1 cigarette smoker in the home. Percentage of agreement of positive cotinine level and caregiver report of a smoker in the home was moderate at 65% ($\kappa = 0.30$, $P = .003$), indicating some misclassification of SHS exposure based on caregiver report. One third of smokers were identified as the caregiver.

SABA Use and Health Care Usage Characteristics

The use of SABA was high, with more than one fourth (27%) reporting daily use during the past 2 weeks. Mean number of SABA fills over 12 months was 3.12 (SD 2.8, range 0–18 fills). There was no seasonal trend for mean SABA fills ($F = 0.49$, $df = 3$, $P = .69$). One fourth of children had at least 4 SABA fills during 12 months and 16% had at least 6 SABA fills during the same period. Health care

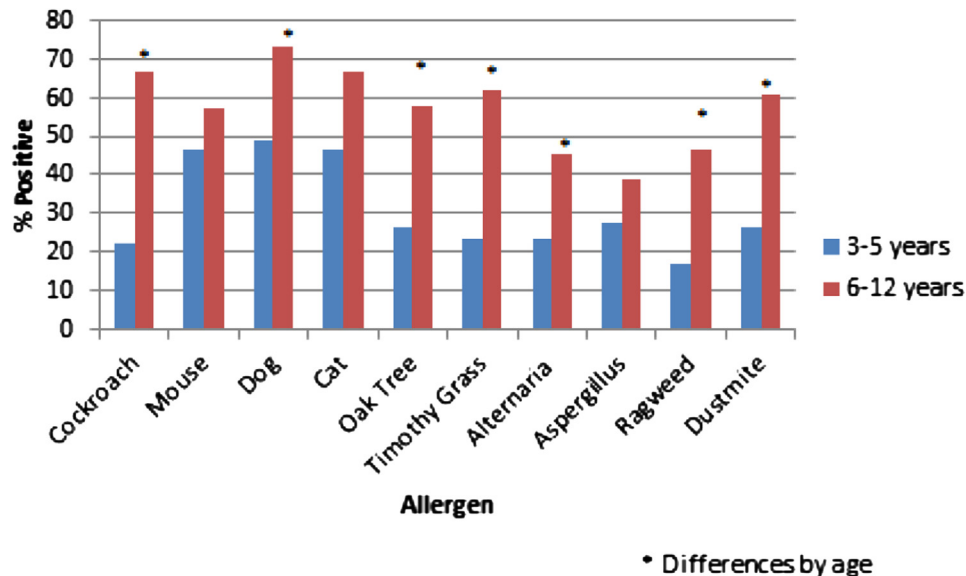


Figure 3. Percentage of children with positive allergen sensitization by age group (* $P \leq .05$).

usage was high, with mean ED visits in the past 3 months at 1.37 (SD 1.0) and mean hospitalizations at 0.12 (SD 0.4) during same period. Further, almost one third (31%) had a confirmed lifetime ICU asthma admission. Despite high SABA use, high ED usage, and many with prior ICU admission for asthma, most caregivers rated their child's asthma control as well controlled (51%) at baseline.

Factors Associated with High SABA Medication Use

Based on the unadjusted bivariate analysis, children with high SABA use were more than 5 times more likely to have a hospitalization for asthma within the past 3 months than children with low to moderate SABA use (Table 2). Further, children with high SABA use were almost 3 times more likely to have a prior ICU admission, more than 3 times more likely to have received specialty asthma care for asthma, and 3 times more likely to have positive cockroach sensitization. Mean number of PCP visits was almost twice as high for the high SABA use group as for the low to moderate SABA use group. Mean ICS fills were almost 4 times higher in the high than in the low to moderate SABA use group (low to moderate SABA, mean 1.31, SD 2.2; high SABA, mean 4.07, SD 3.5, $P < .001$), indicating controller medication use with high SABA use. Residing with a smoker in the home was not significantly associated with high SABA use, although two thirds of the high SABA use group reported a smoker in the home vs only half of the low to moderate SABA use group. A positive cotinine level and reported mouse or cockroach exposure in the home were not associated with high SABA use. Season of the ED enrollment visit was not associated with high SABA use ($\chi^2 = 3.20$, $df = 3$, $P = .36$).

The final stepwise multivariate logistic regression model assessing the impact of select variables on high SABA use contained 6 independent variables (number of ICS fills, cockroach sensitization, prior ICU asthma admission, receipt of asthma specialty care, child age, and income). The results indicated that for every additional ICS fill, a child was 1.4 times more likely to have high SABA fills and a child having a positive cockroach sensitization was almost 7 times more likely to have high SABA fills while controlling for prior ICU asthma admission, receiving asthma specialty care, child age, and income (Table 3). The model as a whole explained 0.28 (Cox and Snell R^2) to 0.41 (Nagelkerke R^2) of the variance in high SABA use and correctly classified 74% of cases. Comparable results (ie, number of ICS fills and positive cockroach sensitization significantly associated with high SABA fills) were obtained when

all variables (number of ICS fills, cockroach sensitization, prior ICU asthma admission, receipt of asthma specialty care, child age and caregiver age, income, and cotinine level) were entered into the multiple logistic regression model.

Discussion

The present data indicate that increased ICS use was significantly associated with high SABA use, indicating high SABA users received some exposure to anti-inflammatory medication. Treating acute symptoms with SABA medication could be a reminder or motivator for filling a controller medication or some caregivers might believe that acute exacerbations require treatment with SABA and ICS medications¹¹ or is in their asthma action plan for the "yellow zone." Alternatively, the dosage of anti-inflammatory coverage might be insufficient to decrease bronchial inflammation and a step-up in therapy might have been indicated but was not achieved.

Moreover, increased ICS use with high SABA use could indicate inadequate inhaler technique (ie, insufficient drug delivery of the 2 medications). Monitoring inhaler technique is an important component of pharmacologic management of asthma.³⁰ National asthma guidelines recommend a minimum of 2 nonurgent asthma clinic visits per 12 months and/or referral to an asthma specialist for children with persistent or poorly controlled asthma to include monitoring of inhaler device technique.¹³ The present data show that only 54% of all participants reported a routine asthma visit with their PCP during the past 3 months yet had at least 1 ED asthma visit during the same period. Further, only 20% of these children reported receiving any asthma specialty care. These PCP visits could have resulted in missed opportunities for guideline-based practice to (1) identify high SABA use, (2) assess inhaler device technique, (3) adjust dosage of anti-inflammatory medication, and (4) refer children with more severe asthma to an asthma specialist.

Because many asthma exacerbations in children are preceded by exposure to environmental triggers,³¹ the authors examined exposures to common indoor allergens and SHS for an association with high SABA use to understand their potential impact on SABA overuse. Almost half of all families reported exposure to cockroach and/or mouse, posing a high allergen burden on these children and consistent with the increased prevalence of American cockroach sensitization in Thai children with asthma.³² Positive cockroach

Table 2

High SABA use by sociodemographic and health characteristics by (N = 100)

Characteristic	Low to moderate SABA use (n = 73)	High SABA use (n = 27)	Total (N = 100)	Statistic
Sociodemographic characteristics				
Child age (y)				
3–5	36 (49.3)	14 (51.9)	50 (50.0)	OR 0.90 (95% CI 0.37–2.19)
6–12 (reference group)	37 (50.7)	13 (48.1)	50 (50.0)	
Caregiver age (y), mean (SD)	31.56 (8.3)	32.27 (6.6)	31.76 (7.8)	$F = 0.15, df = 1, P = .70$
Health characteristics				
Specialty care for asthma				
Yes	10 (13.7)	10 (37.0)	20 (20.0)	OR 3.71 (05% CI 1.33–10.35)
No (reference group)	63 (86.3)	17 (63.0)	88 (80.0)	
ICU or ventilator in past (confirmed)				
Yes	18 (24.7)	13 (48.1)	31 (31.0)	OR 2.84 (95% CI 1.13–7.15) ^b
No (reference group)	55 (75.3)	14 (51.9)	69 (69.0)	
Number of PCP visits for asthma routine care in past 3 mo, mean (SD)	0.70 (0.88)	1.37 (1.4)	0.88 (1.08)	$F = 8.25, df = 1, P = .005$
ED visit for asthma in past 3 mo				
Yes	57 (78.1)	24 (88.9)	81 (81.0)	OR 2.25 (95% CI 0.60–8.42)
No	16 (21.9)	3 (11.1)	19 (19.0)	
Hospitalized for asthma in past 3 mo				
Yes	4 (5.6)	7 (25.9)	11 (11.2)	OR 5.86 (95% CI 1.56–22.08) ^a
No	67 (94.4)	20 (74.1)	87 (88.8)	
Number of symptom days in past 2 wk, mean (SD)	5.03 (4.5)	6.22 (4.7)	5.35 (4.6)	$F = 1.36, df = 1, P = .25$
Number of symptom nights in past 2 wk, mean (SD)	5.70 (7.9)	6.96 (8.5)	6.04 (8.1)	$F = 0.48, df = 1, P = .49$
Asthma controlled (parent report) (n = 92)				
Yes	38 (56.7)	13 (50.0)	51 (54.8)	OR 1.31 (95% CI 0.53–3.25)
No (reference group)	29 (43.3)	13 (50.0)	42 (45.2)	
Medication use characteristics				
Rescue medication canister duration (200 sprays)				
<1 mo	18 (25.4)	12 (44.4)	30 (30.6)	OR 0.43 (95% CI 0.17–1.07)
≥1 mo	53 (74.6)	15 (55.60)	68 (69.4)	
ICS fills in past 12 mo, mean (SD)	1.31 (2.2)	4.07 (3.5)	2.09 (2.9)	$F = 21.0, df = 1, P < .001$
Indoor exposures and allergen sensitization results				
Smoker in home				
0 (reference)	36 (49.3)	9 (33.3)	45 (45.0)	OR 1.95 (95% CI 0.77–4.89)
≥1	37 (50.7)	18 (66.7)	55 (55.0)	
Mother is smoker				
Yes	14 (19.2)	5 (18.5)	19 (19.0)	OR 0.96 (95% CI 0.31–2.97)
No	59 (80.8)	22 (81.5)	81 (81.0)	
Cotinine at baseline				
Positive (≥1.0 ng/mL)	39 (53.2)	14 (53.8)	53 (54.1)	OR 0.99 (95% CI 0.40–2.43)
Negative (<1.0 ng/mL)	33 (45.8)	12 (46.2)	45 (45.9)	
Cotinine, mean (SD)	1.98 (2.0)	2.79 (4.6)	2.19 (2.9)	$t = -1.23, P = .22$
Any positive allergy test result ^c				
Yes	56 (80.0)	19 (82.6)	75 (80.6)	OR 1.19 (95% CI 0.35–4.05)
No	14 (20.0)	4 (17.4)	18 (19.4)	
Cockroach sensitization				
Positive	25 (37.3)	15 (65.2)	40 (44.4)	OR 3.15 (95% CI 1.17–8.48) ^b
Negative	42 (62.7)	8 (34.8)	50 (55.6)	
Cockroach noted in home in past 3 mo				
Yes	34 (46.6)	11 (40.7)	45 (45.0)	OR 1.27 (95% CI 0.52–3.10)
No	39 (53.4)	16 (59.3)	55 (55.0)	
Mice noted in home in past 3 mo				
Yes	35 (47.9)	15 (55.6)	50 (50.0)	OR 0.74 (95% CI 0.30–1.79)
No	38 (52.1)	12 (44.4)	50 (50.0)	

Abbreviations: CI, confidence interval; ED, emergency department; ICS, inhaled corticosteroid; ICU, intensive care unit; PCP, primary care provider; SABA, short-acting β_2 -agonist.^aP ≤ .01.^bP ≤ .05.^cMouse, cat, dog, *Alternaria alternata*, *Aspergillus fumigatus*, oak tree, timothy grass, *Dermatophagoides farinae*, and common ragweed IgE sensitizations (P > .10) between high and low to moderate SABA fills during past 12 months.

sensitization was associated with an almost 7-fold risk of high SABA use, suggesting that the combination of sensitization and exposure to cockroaches is a key contributor to asthma morbidity in inner-city children as suggested in prior reports.³³ Because only one third of children had received prior allergy testing, most caregivers might be unaware of their child's sensitization to cockroach and the increased risk for symptoms with exposure. Prevention of symptoms in children with cockroach sensitivity requires exposure to

the lowest achievable level, often difficult to achieve for inner-city children residing in multiunit dwellings.³⁴ This inability to adequately remediate rodent and pest exposures could have contributed to the high morbidity noted in this group of children. In addition, tailoring home environmental control interventions based on the child's positive sensitizations might be easier to implement than a more comprehensive nontargeted intervention. If cockroaches are present in the child's home, abatement

Table 3

Multivariate regression model^a predicting high short-acting β_2 -agonist use (n = 70 cases for full model)

Baseline characteristic	B (SE)	OR (95% CI)
Number of ICS fills during 12 mo	0.36 (0.15)	1.43 (1.07–1.93) ^b
Cockroach allergy sensitization		
Yes	1.94 (0.85)	6.97 (1.32–36.70) ^b
No (reference)		
ICU admission ever		
Yes	1.41 (0.77)	4.08 (0.90–18.52)
No (reference)		
Asthma special care in past 2 y		
Yes	1.45 (0.80)	4.28 (0.89–20.58)
No (reference)		
Child age (y)		
6–12	–1.50 (0.88)	0.22 (0.04–1.26)
3–5 (reference)		
Income		
\$0–\$19,000 (reference)	1.18 (0.83)	3.27 (0.64–16.73)
\$20,000–\$39,000	0.74 (0.99)	2.09 (0.30–14.54)
>\$40,000		

Abbreviations: CI, confidence interval; ICS, inhaled corticosteroid; ICU, intensive care unit.

^aForward stepwise regression (selection entry criterion, $P = .35$; exclusion criterion, $P > .30$). Variables excluded were caregiver age, child sex, and baseline cotinine level.

^b $P < .05$ (Cox and Snell $R^2 = 0.28$, Nagelkerke $R^2 = 0.41$; Hosmer and Lemeshow test for model, $\chi^2 = 11.2$, $df = 8$, $P = .19$).

measures, including integrated pest management, are recommended.³⁴ Further, subcutaneous cockroach immunotherapy has been shown to be effective in adult pilot studies.³⁵

Overuse of SABA is associated with greater health care usage.¹⁵ A 5-fold higher rate of hospitalization within the past 3 months and an almost 3-fold higher rate of having a prior ICU admission in children with high SABA use were noted compared with children with low to moderate SABA use. Parent report of daily SABA medication has been associated with very poor asthma control.³⁶ Overuse of SABA could be due in part to parental misunderstanding or non-adherence and/or inadequate or inappropriate controller stepwise treatment prescribing by health care providers.³⁶ Although SABAs and long-acting β -agonists provide bronchodilation and relieve asthma symptoms, none of the inhaled β -agonists modify the underlying inflammatory process in the lungs.³⁷ It has been suggested that the development of a tolerance to β_2 -agonists can occur particularly with increasing bronchoconstriction³⁸ and might explain the cause of asthma deaths outside the hospital in patients who fail to respond to SABA medications as emergency treatment in the home³⁸ and the high prior ICU admission rate. Alternatively, half of the caregivers of high SABA users reported their child's asthma was controlled, indicating that a large proportion of caregivers perceived their child's asthma was controlled despite excessive SABA use. Caregiver definition of well-controlled asthma might be based on the availability and response to SABA rather than recognition of symptom severity. Tolerance to SABA medication can be reversed with ICSs, yet low ICS adherence is known to exist in minority inner-city populations as reported in the present results.^{4,5,11,39}

The lack of association between SHS exposure and high SABA use was surprising but consistent with a prior report of a comparable sample of inner-city children.¹⁰ Despite parental awareness that SHS exacerbates asthma, 40% to 67% of inner-city children with asthma reside in a household with at least 1 smoker.^{10,27} The present high rate of SHS exposure (54%) is consistent with multiple inner-city asthma studies.^{10,22,26} Avoidance of SHS exposures is a key component of national and international guidelines for management of childhood asthma.¹³ Unlike the authors' prior studies, the caregiver was not the predominant household smoker and the

caregiver might be unable to institute a total home smoking ban without cooperation from all household members. Anecdotally, several children resided in households owned by a grandparent who smoked cigarettes. This could result in the caregiver choosing between continued SHS exposure and seeking alternative housing when resources are scarce. In addition, prior studies have indicated that many caregivers have a misperception that limiting smoking to certain areas of the house (eg, basement or bathroom) will sufficiently decrease SHS exposure to their children and are unaware of the ubiquitous penetration of SHS in the home.²³

Several clinical implications can be drawn from this study. The use of biomarkers to identify potential sensitizations to environmental allergens can be used to target specific home remediation interventions. For example, knowledge of positive cockroach sensitization without dust mite sensitization can result in a targeted pest management intervention rather than a costly comprehensive intervention. Providers should consider routine cotinine screening for children identified with uncontrolled asthma. Moreover, identification of high SABA users could prompt PCPs and ED providers to observe inhaler technique and perform stepwise controller therapy adjustments to achieve and maintain well-controlled asthma. If providers are not confident about instituting stepwise therapy, referral to specialty care should be considered to identify comorbidities, obtain allergy testing, and individualize environmental control recommendations and receipt of appropriate guideline-based therapy.

There are potential limitations associated with this study. Use of pharmacy claims data for SABA fills is not a direct measurement of SABA use because there could be loss and/or sharing of canisters dispensed. High SABA fills could reflect family sharing of medications and could have resulted in an overestimation of SABA canisters dispensed. Further, generalizability of the results is limited because the authors purposely recruited children with more severe or uncontrolled asthma to maximize their ability to detect a difference in asthma morbidity and health care usage with this intervention. Thus, the present sample of children might have more uncontrolled asthma than the general pediatric asthma population.

In conclusion, one goal of guideline-based asthma therapy is to minimize the need for SABA medications, yet the authors observed overuse of SABA medications with reported concomitant controller medication use. One contributor to SABA overuse could be unknown sensitization to common allergens, with positive sensitization to cockroach allergen among the most risky. The results of this study support monitoring of SABA use, evaluation of allergen sensitization and exposure, screening for SHS exposure, and appropriate prescribing and use of controller medications to improve asthma control in inner-city children with asthma.

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