5-4-2016

The Relationship between Secondhand Tobacco Smoke Exposure and Asthma Severity among the Pediatric Population in Connecticut

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B.A., Pace University, 2007

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Public Health

At the

University of Connecticut

2016

APPROVAL PAGE

Master of Public Health

The Relationship between Secondhand Tobacco Smoke Exposure and Asthma Severity among the Pediatric Population in Connecticut

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2016

ACKNOWLEDGMENTS

I am very grateful for the guidance of Dr. Michelle Cloutier, M.D. and the assistance of Dr. Jessica Hollenbach, Ph.D. in completing this project, without either of whom it would not have been possible, as well as the complex statistical analysis by Dr. Elizabeth Schifano, Ph.D. I am equally grateful for the direction provided by my advisor, Dr. Jane Ungemack, Dr.P.H., and my associate advisor, Dr. David Gregorio, Ph.D, M.S.

My eternal gratitude and love go to my wife, Caroline Hammel, for her unwavering support through this project and the plentiful tribulations of the MD-MPH dual degree program, to our wonderful son, Oliver, and to our parents, Todd Barnet, Patricia Hammel, Thomas Mooney, and Marlee Mooney, each of whom has given of themselves tirelessly during this journey.

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ABSTRACT

Background: Secondhand tobacco smoke exposure (STSE) has been associated with an increased incidence of asthma exacerbations, but the relationship between STSE and asthma severity is less clear.

Objective: To determine whether STSE is associated with asthma severity in children living in Connecticut who have physician-diagnosed asthma and to examine whether it is modified by common markers of community-level socioeconomic status (SES) using the *Five Connecticuts* study.

Methods: The Easy Breathing database identified 32,691 children with physician-diagnosed asthma living in 161 towns in Connecticut. This large database was linked by participant zip code to census data, allowing classification by community, with the five categories described in the *Five Connecticuts* study were used as proxies for levels of SES. Statistical analysis involved multinomial logistic regression models adjusted for enrollment date, sex, age, race/ethnicity, community type, insurance type, family history of asthma, eczema, and exposure to secondhand tobacco smoke, dogs, cats, gas stove, rodents, and cockroaches. We modeled asthma severity according to the standard classification system of mild persistent, moderate persistent, severe persistent, or intermittent asthma subtypes.

Results: For the Easy Breathing program participant, STSE was significantly associated with mild and moderate persistent asthma (aRRR: 1.09 [1.02, 1.17] and aRRR: 1.11 [1.02, 1.21]

respectively). In analyses stratified by STSE, race/ethnicity (p=0.004) and insurance type (p<0.0001) were overall predictors of persistent asthma and demonstrated specifically that Puerto Rican ethnicity (aRRR: 1.50 [1.17, 1.92]) and public insurance coverage (aRRR: 1.57 [1.30, 1.90]) were significant risk factors for moderate persistent asthma.

Conclusion: Children with STSE in Connecticut who have Puerto Rican ethnicity or public insurance are at higher risk for moderate persistent asthma. This association did not hold for other degrees of asthma severity, including the more severe "severe persistent" subtype (for which there was insufficient power in our study), or for other indicators of SES. Given the unexpected absence of these further associations, further research is needed to illuminate the complex interrelationship between STSE, asthma severity, and SES. Our somewhat unexpected results were thought to reflect a complex picture in which race/ethnicity, environment, and development are all major factors for asthma severity, and also reiterated the ongoing question in asthma literature of whether different severities of asthma represent distinct disease entities.

INTRODUCTION

Asthma is a chronic disease of the airways that is common among children in the United States (CDC, 2011). Children with asthma suffer from a narrowing of the airways accompanied by inflammation, bronchospasm, and increased mucus production, resulting in numerous symptoms including shortness of breath, chest tightness or pain, wheezing, and coughing. Aside from the healthcare expenses they incur, asthma attacks, or exacerbations, can be life-threatening. Children with asthma are frequently treated with several different medications and are required to keep rescue inhalers at every location where they spend a significant amount of time, including home, school, and at the locations of extracurricular activities (Mayo Clinic, 2015).

This disease results in numerous visits to doctors' offices, emergency departments, and outpatient hospital clinics, affecting tens of millions of children and resulting in costs reaching into the tens of billions of dollars. More difficult to quantify is the social cost of asthma: parents losing sleep over worry that their child will stop breathing, children hesitating to participate in exercise activities for fear of causing an asthma exacerbation, and doctors concerned about finding the right balance between adequately treating a child with asthma and not wanting to prescribe multiple medications, including some with documented longterm effects, to a young patient (Wang, 2014).

There are also racial and socioeconomic disparities in asthma prevalence rates. Black children are affected more than White, and the asthma rates among Puerto Rican children are far above those of any other ethnicity. Rates are also higher among children whose parents live below the

federal poverty line (CDC, 2015). Children exposed to secondhand tobacco smoke are also at an increased risk of developing asthma. Within Connecticut, children in poor urban areas are disproportionately hospitalized, with the rate in Hartford, Connecticut approximately six times that of the neighboring city, West Hartford (Surveillance Report, 2016). One reason for this may involve poorer asthma management education within disadvantaged communities secondary to less access to primary healthcare, which itself is related to the poor public transportation within Hartford specifically. However, there are also recognized "basic environmental issues" such as STSE, air pollution, cockroach droppings, and other airborne allergens within urban communities which comprise an ongoing obstacle for asthma prevention and treatment (Cloutier, 2002). To what extent this is due to the predominantly disadvantaged population within Hartford versus its urbanicity is unclear.

It has been well-supported in the literature that secondhand tobacco smoke exposure (STSE) is associated with an increased prevalence rate of asthma (Vernon, 2012). However, less well-understood is the impact of STSE on asthma severity. Given that STSE is known to be associated with such a major public health issue, further exploration of this topic is indicated. Because of the high prevalence of asthma and its widespread negative impact on public health, this study adopts a population-based, rather than clinical, approach. The purpose of this study is to determine whether STSE impacts asthma severity among children with physician-diagnosed asthma in Connecticut and whether and to what extent socioeconomic factors including race, poverty, and community type impact that association. This will contribute to a better understanding of the myriad negative impacts of STSE, which could lead to further public health

initiatives to help prevent STSE in children and, subsequently, reduce asthma morbidity and mortality, as well as healthcare burden, at the national level.

LITERATURE REVIEW

In the United States, the total asthma prevalence among children less than 18 years of age is 7.3%, indicating over 22 million affected children (CDC, 2015). As a result of its high prevalence, asthma is a burden for the healthcare system. In 2011, there were 1.8 million emergency department visits with asthma as the primary diagnosis among children and adults combined. According to the CDC, in 2010, there were 14.2 million physician visits for asthma, as well as 1.3 million hospital outpatient department visits in the same year. At an estimated baseline cost of approximately $1502 per emergency department visit, this represents a cost to the healthcare system of $2.7 billion (Wang, 2014). The costs incurred via physician office visits and outpatient hospital visits only compound this number. That same study estimates that asthma costs the United States $56 billion annually.

There are significant racial and socioeconomic disparities within asthma prevalence rates, as well. The total asthma prevalence among children of age less than 18 years is 7.3%. Among Black children, however, the prevalence is 13.4%, and among Puerto Rican children, it is 20.7% (CDC, 2016). These rates represent nearly two and nearly three times the national average, respectively.

Furthermore, for those below the federal poverty threshold, the prevalence is 10.9%, i.e. approximately 5,321,000 children, which is roughly 50% higher than the average (CDC, 2016). These numbers are further dramatized in hospitalization rates: within annual inpatient hospital discharges for asthma, among White children the rate was 8.7 per 10,000, but for Black children, the rate is 29.9 per 10,000, representing an increase of 243% (CDC, 2016).

Aside from asthma's consequential morbidity, perhaps of greater relevance to the public health field is its mortality. Asthma mortality among children less than 18 years of age is 3.0 per million. Among all people with asthma, racial disparities again become obvious: while the data for pediatric population mortality by race is not available through the CDC, the total mortality rate among White adult and pediatric patients combined is 8.4 per million, but it is 25.9 among Black patients, which is more than three times that of White patients (CDC, 2016). It is unlikely that these racial disparities are solely explained by the adult populations.

The pathogenesis of asthma is unknown, but the strongest predisposing factor is atopy, a condition in which one is genetically predisposed to forming antibodies (IgE subtype) against common environmental allergens. This gives rise to the colloquial term "allergic asthma." This predisposition is particularly strong for African-American and Puerto Rican children in Connecticut (Celedón, 2004). The pathogenesis of asthma may also involve an imbalance of T helper 1 (Th1) and T helper 2 (Th2) cells, in which a preponderance of Th2 cells facilitates the activation of mast cells by allergens. The mast cells then release histamine, a mediator of bronchoconstriction, which then results in asthma symptoms. In short, inhalation of aeroallergens to which an individual has become sensitized, substances present within particular environments,

causes an immune response within the body that results in inflammation, swelling, and mucus production within the airways, the constellation of which is known as asthma (Expert Panel, 2007).

The risk factors of pediatric asthma include atopy, wheezing before age 3, allergic rhinitis, secondhand tobacco smoke exposure (STSE), residential exposures (pets, gas stoves, damp environments, mold) (Lyons, 2011), maternal smoke exposure during pregnancy (Cohen, 2010), respiratory infections early in life, exposure to acetaminophen or ibuprofen (limited evidence), daycare attendance before age 2, obesity, and genetic associations (complex and in need of further study) (Melen, 2013). Ethnicity is a risk factor, regardless of socioeconomic status (SES). Puerto Ricans have the highest prevalence rates, as well as the highest emergency department use (Coffey, 2012).

The connection between exposure to STSE and asthma incidence, as well as triggering of asthma exacerbations, has been made previously (Vernon, 2012; Weiss, 1994; Yang, 2012). Less well understood is the correlation between exposure to STSE and the severity of asthma disease. Although studies have been published on other predictors of severity of disease in children (Ramsey 2005), a search of PubMed revealed only one publication regarding this issue (Mannino, 2002). While Mannino et al. showed a correlation between moderate or severe asthma and smoking exposure (OR = 2.7), it was a relatively small study (n = 523), relied on self-reported asthma severity, and has not been replicated since its publication in 2002.

Pediatric asthma is a public health issue that poses significant burdens both on the healthcare system and on the quality of life of children living with this disease. Determining the link between severity of this burdensome disease and exposure to a preventable association and trigger, STSE, could help improve prevention, patient care, and outcomes. Whether STSE increases the severity of asthma is a predominantly unexplored topic. Few studies have been done, and none have previously been completed in Connecticut. Our primary objective was to determine the association between exposure to STSE and asthma severity among children enrolled in the Easy Breathing program in Connecticut. Secondary objectives were to disentangle the effects of SES and race/ethnicity on asthma severity with respect to exposure to STSE.

MATERIALS AND METHODS

Description of Study

This study is a secondary analysis of data from a validated screening survey of all children enrolled in the Easy Breathing asthma program in Connecticut between April 1, 1996 and September 30, 2013. Easy Breathing is a program which translates the several hundred page-long National Asthma Education and Prevention Program (NAEPP) guidelines into a format accessible and implementable by physicians (EPR-3, 2007). Specifically, it guides clinicians to classify asthma severity according to the NAEPP 2007 Guidelines using a validated survey tool (Hall, 2001). This paper uses responses to the Easy Breathing surveys as its source of data for secondary analysis. This database provides an opportunity to apply the data of over 32,000

children with physician-diagnosed asthma to determine above objectives within a large sample size.

Asthma is a clinical diagnosis, meaning that there is no laboratory test to objectively confirm or refute its presence. Instead, diagnoses are made by physicians based on guidelines and clinical judgment. Physicians used the materials from Easy Breathing to obtain an understanding the national guidelines on asthma diagnosis, which they then used to help determine disease presence and severity. Asthma severity was based on four previously-validated questions: *Frequency of episodes of cough, wheeze, shortness of breath (daytime)*, *Frequency of nighttime symptoms, Exercise impairment (even with pre-treatment with beta-agonist),* and *School absenteeism for asthma past year (days/month)* and classified as intermittent, mild persistent, moderate persistent, or severe persistent (Higgins, 2005).

The association of STSE and asthma severity (mild, moderate, and severe persistent vs. intermittent) was assessed by multinomial logistic regression analysis and presented as relative risk ratio (RRR) or as RRR adjusted (aRRR) for potential confounders and 95% confidence interval (95% CI). Analyses were adjusted for enrollment date, sex, age, race/ethnicity, family history of asthma, community type, type of insurance (public or other), eczema status, and exposure to dogs, cats, rodents, cockroaches and gas stoves. Interactions between STSE and confounders such as sex, age, race/ethnicity, insurance type, and community type were tested. Due to the significant interaction between STSE status with insurance type, we conducted stratified analyses by STSE. All results are reported using multiple imputation (MI) to handle

missing values in the predictor variables unless otherwise noted. All analyses were performed with SAS version 9.4 (SAS Institute, Cary NC).

Target Population

Clinicians who employed the Easy Breathing program were encouraged to screen all of their patients for asthma using its survey. This sample includes 30,163 children in Connecticut with physician-diagnosed asthma and documented severity level. Because of the difficulty of diagnosing asthma in infants, only children six months of age and older were enrolled into the program.

Data Set

Because of potential discrepancies between the practices of different physicians who employ Easy Breathing, as well as their variable patient populations, the study population represents a convenience sample rather than a true random sample. However, because of the large size of the sample, it may actually better represent the population of children with which we are most concerned, so the extent to which it is a convenience sample has minimal, if any, bearing on the study results. This illuminates one of the limitations of our study: that the children included, given that they are presenting to physicians, could have more disease and greater disease severity than the general public. This introduction of bias creates a potential confounder which could diminish our ability to distinguish the relationships among variables. However, the impact of this confounder is limited by the fact that physicians were asked to screen all of their pediatric patients for asthma, not just those who had concerning symptoms.

To evaluate the effect of community type on asthma severity, town of residence (as measured by participant's zip code, where multiple zip codes within a town were combined to represent that town) was classified according to the *Five Connecticuts* study as urban core, urban periphery, suburban, wealthy, or rural as proxies for community type (Ramsey, 2005). These proxies were determined by combining town-level population density, median family income, and percent of residents living in poverty (defined as the percentage of population below the 100% poverty threshold) (Figure 1). Importantly, race/ethnicity was not used to determine group membership. Because there were relatively few people with asthma sampled from the wealthy areas, this category was combined with the suburban category and classified as "suburban/wealthy". This was done because, when compared to national averages, Connecticut's statewide demographic averages provided misleading descriptions of SES. The report released in May 2004 provided a more representative description of town demographics that highlighted inequalities at the town level often not clearly discernible at the county level.

Demographic information on each child including age, gender, ethnicity, town of residence, insurance (Medicaid or Other), presence or absence of eczema, family history of asthma, secondhand tobacco smoke exposure (STSE), and exposure to known asthma triggers were self-reported from the Easy Breathing survey.

STSE was dichotomized into Yes or No based on response to the following question on the Easy Breathing survey: *Is your child exposed to the following more than 2 times/week? Cigarette or Cigar smoke.*

Variables

We included covariates previously associated with increased risk of having persistent asthma and/or with risk for STSE exposure. Potential confounders were collected from the Easy Breathing survey and included child age, sex, race/ethnicity, family history of asthma, type of health insurance, history of eczema, and exposure to cats, dogs, cockroaches, gas stove, and rodents. Age was dichotomized into two age groups: less than or equal to 5 years or greater than 5 years. Race/ethnicity was determined by choosing any of the following options: African American, Asian or Pacific Islander, Caribbean/Virgin Islander, White/Caucasian, Hispanic Mexican, Hispanic/Puerto Rican, Hispanic/Cuban, and Hispanic/Other.

Analysis

The association of STSE and asthma severity was assessed by multinomial logistic regression analysis and presented as relative risk ratio (RRR) or as RRR adjusted (aRRR) for potential confounders (listed above), which were used to adjust the results. We also tested interactions between STSE and confounders such as sex, age, race/ethnicity, insurance type, and community type. Due to the significant interaction between STSE with race/ethnicity, we also conducted stratified analyses by STSE.

RESULTS

Population Characteristics

Participants were children aged six months to 18 years living in 161 different towns in Connecticut. Overall, of the 120,854 children enrolled in the Easy Breathing program in Connecticut, 32,691 (27%) had a physician-confirmed diagnosis of asthma, and 30,163 (97% of those with asthma) had documented asthma severity and were included in this analysis (Table 1). Because clinicians participating in Easy Breathing are encouraged to screen all children (with and without asthma) into the program, the demographics of the analytic population reflect those of all children in Connecticut, with comparable rates of STSE (Bureau USC, 2010).

STSE Exposure

Children with asthma had STSE almost twice as often as children without asthma (23% vs 13% respectively, $p<0.0001$). STSE differed significantly by race/ethnicity, community type, and insurance status. Black, Hispanic, Puerto Rican children with asthma had STSE more frequently than Caucasian children (OR 2.0, 95% CI 1.8-2.1, OR 1.4, 95% CI1.3-1.6, OR 2.1, 95% CI 1.9-2.2, respectively and Table 2). Children with asthma living in the urban core, urban periphery, and rural areas were more likely to have STSE than children living in suburban/wealthy areas (OR 3.6, 95% CI 3.3-4.0, OR 2.2, 95% CI 2.0-2.5, and OR 2.3, 95% CI 2.0-2.6 respectively and Table 2). Children with asthma having public insurance (i.e. Medicaid) were more likely to have STSE than privately insured children (OR 3.0, 95% CI 2.8-3.2).

STSE and Asthma Severity

Among children with asthma, the relation of STSE to asthma severity levels was assessed (Table 3). In unadjusted models, exposure to STSE was associated with a significant risk for persistent

asthma as compared to intermittent asthma (Table 2). In adjusted models, STSE was a significant risk factor for mild and moderate persistent asthma (Table 3).

SES and Other Confounders

Significant predictors of persistent asthma included Black race, non-Puerto Rican Hispanic ethnicity, Puerto Rican ethnicity. For moderate persistent asthma specifically, these races and ethnicities created significantly higher risk. Community type was also a significant risk factor, with the urban core, urban periphery, and rural areas all increasing risk for moderate persistent asthma when compared to children living in suburban/wealth areas. In models unadjusted for covariates, other risk factors for greater asthma severity included positive family history of asthma, public insurance, eczema, exposure to cockroaches, and gas stoves (Table 2). Lastly, children with public insurance experienced greater risk for mild and moderate persistent asthma than children with private insurance.

In the multinomial regression model, an interaction between STSE and insurance status was present (p=0.0325). Adjusted RRR of STSE compared to no exposure for insurance-stratified models are presented in Table 4. Only aRRR is presented because the crude RR is similar. In adjusted analyses, STSE no longer remained a significant risk factor for persistent asthma severity among children with public insurance, whereas children with private insurance and STSE retained an increased risk of persistent asthma (OR 1.23, 95% CI 1.11-1.37). This observation could be accounted for by Caucasian children with private insurance and STSE (OR 1.25, 95% CI 1.1-1.4, Table 5). Puerto Rican children, irrespective of insurance status, STSE status, or community type, were more likely to be diagnosed with persistent asthma. While Black

children were also more likely to be diagnosed with persistent asthma, this association did not hold for those with public insurance (Table 4).

DISCUSSION

Although STSE is associated with increased risk for asthma incidence and is a suspected precipitator of exacerbations, the relationship between STSE and the severity of asthma in children has not been ascertained previously. This is the first large-scale study to our knowledge to examine the association between exposure to STSE and asthma severity. In this study of children with a physician confirmed diagnosis of asthma, STSE was associated with a greater risk for mild and moderate persistent asthma, regardless of race/ethnicity and community type. Children with severe persistent asthma tended to have higher relative risk factors, but the larger standard errors, which were due to small sample sizes, may have rendered the effects insignificant. Alternatively, it is possible that severe asthma may be a different asthma phenotype. This is supported in the literature, with one study finding that individuals with severe persistent asthma express neutrophilic inflammation rather than eosinophilic, the latter of which is considered a classical sign of asthma inflammation (Fahy, 2009).

The risk for persistent asthma with STSE was modified by insurance status, but not by race/ethnicity or community type. That only children with private insurance demonstrated an increased risk of having a physician-confirmed diagnosis of persistent asthma with STSE suggests several possibilities. First, some physicians do not accept public insurance, and those physicians may have different proclivities with respect to asthma diagnosis, creating a disparity

in the data. Second, insurance type may bias physicians with respect to asthma diagnosis. As mentioned previously, asthma is a diagnosis which requires clinical judgment. This limitation potentially allows bias to influence apparent disease incidence. Third, insurance status may reflect other factors which have a true impact on asthma severity and which have not been explored. The increased risk of persistent asthma in the setting of STSE is particularly important because children with asthma are more likely to have STSE than those without asthma (Quinto, 2013). This suggests that STSE plays a role in both the incidence and severity of asthma.

Urban areas are disproportionately home to poor, racial/ethnic minorities known to be at increased risk for asthma and more severe disease (Levy, 2004; Cloutier, 2008). Our results suggest that when adjusting for various confounders, race/ethnicity is a major predictor of persistent asthma given STSE, and we found it to be similar to recent reports of asthma prevalence (Coffey, 2012; Vernon, 2012). Other recent reports highlight the complexities between STSE, race/ethnicity, and adverse asthma outcomes. Akinbami et al., 2013 reported that STSE was associated with adverse outcomes, including missed school days, urgent care visits, interrupted sleep, activity limitation, and exercise-induced wheezing, among non-Hispanic White but not among Black children with asthma. However, Black children without STSE had similar or greater proportions of adverse outcomes as compared to children of other racial or ethnic groups, regardless of STSE. Our results further support and add to these findings as we also observe no significant contribution of STSE exposure to persistent asthma among Black and Puerto Rican children with asthma. However, among Asian/Pacific Islander and Other children living in the urban core and among Caucasian children living in suburban/wealthy communities,

STSE is a strong risk factor for persistent asthma. These data suggest that race/ethnicity is the major factor driving more persistent asthma among children in Connecticut.

As above, we observed that STSE was associated with greater asthma severity among privately insured children, though publicly-insured children were more likely to report STSE. It is possible that other factors affecting asthma severity are encompassed within race/ethnicity. Puerto Rican and Black children reside disproportionately in the urban core, where exposures associated with lower housing quality (mold, stress) are more prevalent. That community type does not modify the relationship between STSE and asthma severity suggests that smoking cessation efforts should be targeted to all children with persistent asthma irrespective of where they reside.

The use of the Easy Breathing data presents several advantages, including guideline-determined measurement of asthma severity, training of clinicians to ensure the consistent application of those guidelines, and the ability to assign unique area of residence categories, yet several limitations exist. The prevalence of asthma in Connecticut is not 27%. Rather, that is the rate of asthma in children screened and enrolled in Easy Breathing. Therefore, this sample represents a convenience sample of children already seeking care, not a representative sample of all children, or even of all children with asthma. Community type, as a proxy of SES, was based on town-level characteristics and may not represent the child's family income or living conditions. Nevertheless, it is useful to group children within a similar area of residence together to make comparisons between children living in different communities, as the *Five Connecticuts* reflect separate and distinct groups (Five Connecticuts, 2014). Third, there is potential for misclassification of area of residence because subjects were surveyed between 1998 and 2013

but were assigned to year 2000 categories. It is possible that the urbanicity of a given town changed between 2000 and 2013, and so a child living within such a town would be misclassified. Another potential weakness is how STSE was measured. Misclassification bias may have occurred by parents of children with asthma who are aware of smoking's adverse impact on asthma, which would have altered the association between STSE and persistent asthma. In addition, the absence of information on STSE exposure dose was limiting, although it should be noted that STSE biomarkers (cotinine, nicotine) have not been found to enhance the quality of smoking data when examining asthma or asthma-related outcomes (Akinbami, 2013).

CONCLUSION

Overall, our study suggests that exposure to STSE is an independent risk factor for mild and moderate persistent asthma in children enrolled in the Easy Breathing program in Connecticut. The relative contribution of SES and race/ethnicity on the relationship between STSE and asthma severity remains unclear. Here we show that although areas with greater poverty and lower income have higher rates of persistent asthma, STSE is only an independent risk factor in the urban periphery and suburban/wealthy communities, where higher proportions of Caucasians and lower proportions of African Americans and Puerto Ricans reside. This suggests that for children living in a milieu of exposures associated with lower housing quality, the benefits of reducing STSE exposure may be less significant. Overall, African American race and Puerto Rican ethnicity is associated with more persistent asthma. However, these relationships only exist in certain communities. These findings suggest that SES is a major risk factor for persistent

asthma that can be explained by the racial and ethnic makeup of poor urban and rural communities. However, it leaves several questions unanswered.

One possible explanation for why our large sample size and thorough data analysis led to unexpected results is that we underestimated the extent to which race/ethnicity contributes to asthma severity. Another possible explanation is that our classification system for asthma is flawed, which is supported by the finding that severe asthma more often presents neutrophilic rather than eosinophilic inflammatory processes (Fahy, 2009). Thus, rather than viewing qualitative increases within a particular disease entity, we are actually studying several distinct disease processes and, consequently, conflating them in our study. It is also possible that both explanations are true. Considering that there were two primary inconsistencies in our data: first, that STSE was only associated with mild and moderate persistent asthma, but not severe; and second, that there was no association between STSE and non-Puerto Rican Hispanic children or Puerto Rican children, but associations were found for other ethnicities, this picture fits. If this is the case, it would explain why we found no association between STSE and severe persistent asthma, as well as no association between STSE and non-Puerto Rican Hispanic children or Puerto Rican children. Hence, asthma may best be conceived of as a Venn diagram in which race/ethnicity, environment, and development are all major factors.

This study provided some evidence to support this conclusion. For example, Puerto Rican children were more likely to have persistent asthma, although children with asthma and public insurance are exposed more to STSE, it is not poverty *per se* (using public insurance as a proxy for individual wealth) that accounts for the increased risk of greater asthma severity. That STSE

was also found to be an insufficient explanation suggests that another major factor is present. Our study indicates that ethnicity/race is this missing factor.

In conclusion, our work suggests that the concept of STSE as a risk factor for increased asthma severity in children is complex. Unfortunately, though STSE among U.S. children without asthma decreased from 1999-2010, there has been no change in STSE among children with asthma during this period (Quinto, 2013). According to our study, mitigating this exposure may really only matter among children living in more affluent and primarily non-Hispanic Caucasian communities. This work highlights the need for an ecological view of risk for persistent asthma in order to direct research and public health measures effectively and appropriately to prevent and manage childhood asthma. It also indicates the need for further exploration of the etiology of asthma, particularly its genetic contributors.

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Vernon MK, Wiklund I, Bell JA, Dale P, Chapman KR. What do we know about asthma triggers? a review of the literature. The Journal of asthma : official journal of the Association for the Care of Asthma. 2012 Dec;49(10):991-8.

Table 1. Demographics of children with asthma enrolled in Easy Breathing and STSE exposure status				
	Number	%	STSE exposed, %	p value[†]
Asthma	32691	26	23	<0.0001

Wang, T., Srebotnjak, T., Brownell, J., & Hsia, R. Y. (2014). Emergency Department Charges for Asthma-Related Outpatient Visits by Insurance Status. Journal of Health Care for the Poor and Underserved, 25(1), 396–405. http://doi.org/10.1353/hpu.2014.0051

Asthma Severity				
Intermittent	19630	62	21	
Mild Persistent	7888	25	24	<0.0001
Moderate persistent	3818	12	29	
Severe persistent	238	0.8	35	
Public Insurance	12853	45	32	<0.0001
Area of residence				
Urban core	9079	33	29	
Urban periphery	8574	31	20	<0.0001
Rural	2403	9	20	
Suburban/wealthy	7284	27	10	
Race/Ethnicity				
Black*	5150	16	29	
Hispanic**	2581	8	22	<0.0001
Puerto Rican	7321	23	30	
Asian/Pacific Islander	718	2	11	
Caucasian	13135	40	17	
Age Group				
0-4 years	11127	34	20	
5-9 years	10264	31	21	<0.0001
10-14 years	8333	26	24	
15 and older	2967	9	34	
Female (vs male)	14088	44	24	<0.0001
Family History	22597	74	24	<0.0001
Eczema	5610	27	20	<0.0001
Cockroach	2147	7	48	<0.0001
Gas stove	7978	32	31	<0.0001
Dog	10220	31	23	0.32
Cat	6798	21	28	<0.0001
Rodent	1023	3	27	0.001

* Black includes Caribbean/Virgin Islander

** Hispanic includes those identifying as non-Puerto-Rican Hispanic

† Indicates Chi-square analysis of children with non-missing covariates (complete-case)

Table 2. Risk of STSE by Ethnicity, Area of Residence, and Insurance Status

Ethnicity	**OR**	**95% CI**	**P value**
Caucasian	REF		
Hispanic, non-Puerto Rican	1.414	1.270-1.574	<0.0001
Black	1.988	1.840-2.149	<0.0001
Asian/Pacific Islander	0.561	0.436-0.721	<0.0001
Puerto Rican	2.080	1.939-2.230	<0.0001
Area of residence			
Suburban/wealthy	REF		
Urban core	3.625	3.302-3.979	<0.0001
Urban periphery	2.239	2.030-2.469	<0.0001
Rural	2.296	2.012-2.619	<0.0001
Insurance Status			
Private	REF		
Public	3.018	2.841-3.207	<0.0001

Table 3. Main Effects Analysis of Asthma Severity Using Multinomial Logistic Regression with Multiple Imputation (N=30163)					
Risk Factor		**Intermittent**	**Mild Persistent (N=7528)**	**Moderate Persistent**	**Severe Persistent (N=228)**

		N=??? (Reference)		(N=3633)	
Enroll Year[b]		**1.00**	**0.98** (0.98,0.99)[b]	1.00 (0.99,1.01)	**0.87** (0.84,0.90)[b]
Age[b]		**1.00**	**0.97** (0.96,0.97)[b]	**1.02** (1.01,1.03)[b]	1.03 (1.00,1.06)
Family History[b]		**1.00**	**1.22** (1.14,1.31)[b]	**1.49** (1.35,1.64)[b]	1.36 (0.94,1.98)
Gender		**1.00**	**1.06** (1.00,1.12)[a]	1.04 (0.96,1.12)	1.12 (0.85,1.46)
Public Insurance[b]		**1.00**	**1.23** (1.15,1.32)[b]	**1.68** (1.52,1.86)[b]	1.29 (0.89,1.89)
Gas Stove		**1.00**	0.97 (0.91,1.04)	1.08 (0.99,1.18)	1.06 (0.78,1.44)
Eczema[b]		**1.00**	**1.14** (1.06,1.22)[b]	**1.25** (1.14,1.37)[b]	**1.47** (1.06,2.04)[a]
Cockroach[b]		**1.00**	**1.18** (1.05,1.32)[b]	**1.46** (1.28,1.66)[b]	**1.50** (1.02,2.20)[a]
Rodent		**1.00**	1.05 (0.90,1.23)	0.90 (0.72,1.14)	0.79 (0.32,1.95)
Dog		**1.00**	0.96 (0.91,1.03)	0.99 (0.91,1.08)	1.06 (0.77,1.45)
Cat		**1.00**	1.05 (0.98,1.12)	0.93 (0.84,1.03)	0.81 (0.54,1.22)
STSE[a]		**1.00**	**1.07** (1.00,1.15)[a]	**1.11** (1.02,1.22)[a]	1.22 (0.89,1.65)
Area of residence[b]*	Urban Core[b]	**1.00**	**1.18** (1.06,1.30)[b]	**1.56** (1.34,1.82)[b]	1.60 (0.84,3.03)
	Urban Periphery[b]	**1.00**	**1.22** (1.13,1.33)[b]	**1.30** (1.14,1.49)[b]	1.33 (0.74,2.36)
	Rural[b]	**1.00**	1.06 (0.94,1.19)	**1.46** (1.23,1.74)[b]	1.98 (0.95,4.14)
Race/ Ethnicity[b]**	Non-Puerto Rican Hispanic[b]	**1.00**	1.06 (0.95,1.19)	**1.35** (1.15,1.57)[b]	1.46 (0.78,2.71)
	Black[b]	**1.00**	**1.12** (1.02,1.23)[a]	**1.26** (1.10,1.43)[b]	1.19 (0.68,2.07)
	Puerto Rican[b]	**1.00**	**1.21** (1.10,1.33)[b]	**1.59** (1.39,1.81)[b]	**2.09** (1.24,3.52)[b]
	Asian/Pacific Islander	**1.00**	1.09 (0.91, 1.31)	0.96 (0.70, 1.32)	1.36 (0.42, 4.44)

Values are adjusted relative risk ratios (95% CI) from multinomial logistic regression models, relative to Intermittent Asthma (N=18774). The model was adjusted for enrollment date, sex, age, race/ethnicity, family history of asthma, area of residence (SES), type of insurance (public or other), eczema status, and exposure to dogs, cats, rodents, cockroaches and gas stoves. *vs Suburban/Wealthy, **vs Caucasian, [a] p<.05, [b]p<.01. Superscripts on variable names indicate significance across asthma severity levels (Intermittent vs. Persistent Asthma).

Table 4. Adjusted Relative Risk Ratios (aRRR) of Secondhand Tobacco Smoke

Exposed vs. Unexposed Children with Asthma for Persistent Asthma, Stratified by Insurance Status		
	Public Insurance	Private Insurance
	aRRR (95%CI)	aRRR (95% CI)
ETS	1.00 (0.92,1.08)	**1.23** (1.11,1.37)[b]
Race/Ethnicity		
Caucasian	**REF**	
Non-Puerto Rican Hispanic	1.05 (0.91,1.21)	**1.18** (1.00,1.38)[a]
Black	1.06 (0.93,1.21)	**1.18** (1.05,1.33)[b]
Asian/Pacific Islander	1.01 (0.72,1.43)	1.06 (0.87,1.30)
Puerto Rican	**1.20** (1.06,1.36)[b]	**1.47** (1.28,1.68)[b]
Area of Residence		
Suburban/Wealthy	**REF**	
Urban Core	**1.35** (1.14,1.60)[b]	**1.25** (1.10,1.42)[b]
Urban periphery	**1.34** (1.13,1.58)[b]	**1.17** (1.07,1.28)[b]
Rural	1.12 (0.90,1.39)	**1.18** (1.04,1.34)[b]

, [a] p<.05, [b]p<.01. Superscripts on variable names indicate significance across asthma severity levels (Intermittent vs. Persistent Asthma).

Table 4a. Crude Relative Risk Ratios (RRR) of SSE Versus Unexposed Children with Asthma for Persistent Asthma, Stratified by Insurance Status			
		Public Insurance	Private Insurance
		RRR (95%CI)	RRR (95% CI)
SSE		1.06 (0.99,1.15)	**1.31** (1.19,1.45)[b]
Race/Ethn	HISP	**1.23** (1.08,1.39)[b]	**1.32** (1.14,1.54)[b]
Race/Ethn	AA	**1.26** (1.13,1.41)[b]	**1.41** (1.27,1.56)[b]
Race/Ethn	ASIAN	0.97 (0.69,1.35)	1.08 (0.89,1.32)
Race/Ethn	PR	**1.51** (1.37,1.66)[b]	**1.85** (1.65,2.07)[b]
SES	UC	**1.64** (1.42,1.91)[b]	**1.72** (1.56,1.90)[b]
SES	UP	**1.39** (1.18,1.63)[b]	**1.28** (1.18,1.39)[b]
SES	RUR	1.09 (0.88,1.35)	**1.17** (1.03,1.31)[a]

, [a] p<.05, [b]p<.01. Superscripts on variable names indicate significance across asthma severity levels (Intermittent vs. Persistent Asthma). HISP = Hispanic, AA = African American, PR = Puerto Rican, UC = urban core, UP = urban periphery, RUR = rural.

Table 5. Adjusted Relative Risk Ratios (aRRR) for Persistent Asthma, Stratified by Insurance Status and Race/Ethnicity Status

Public																				
Cauc (n ~ 2600)	**OR**	**95% CI**		**Hisp (n ~ 1800)**	**OR**	**95% CI**		**AA (n ~ 3200)**	**OR**	**95% CI**		**PR (n ~ 6000)**	**OR**	**95% CI**		**Asian (n ~ 180)**	**OR**	**95% CI**	
Gender	1.0537	0.8874	1.25114	Gender	1.0908	0.89046	1.33611	Gender	1.09526	0.94307	1.272	Gender	1.0575	0.9488	1.1787	Gender	2.12909	0.93772	4.834
FamilyHx	**1.577**	**1.295**	**1.9198**	FamilyHx	1.1635	0.90926	1.48884	**FamilyHx**	**1.2596**	**1.0448**	**1.519**	FamilyHx	1.164	0.9787	1.3844	FamilyHx	0.81668	0.37254	1.79
Dog	0.9865	0.8315	1.17029	Dog	1.2574	0.98691	1.60204	Dog	0.88893	0.71845	1.0999	Dog	1.0153	0.891	1.1569	Dog	1.0411	0.22357	4.848
Cat	1.086	0.913	1.29171	Cat	1.0742	0.78992	1.46078	**Cat**	**1.4073**	**1.0984**	**1.803**	Cat	0.8553	0.7118	1.0277	Cat	0.44264	0.0871	2.25
STSE	1.0492	0.8734	1.26039	STSE	0.8494	0.67178	1.07403	STSE	1.08687	0.91945	1.2848	STSE	0.9711	0.86	1.0966	STSE	2.37709	0.89181	6.336
agecent	0.988	0.9697	1.00669	agecent	1.0095	0.9873	1.03225	agecent	0.98492	0.96878	1.0013	agecent	0.9927	0.9813	1.0043	agecent	0.96858	0.89255	1.051
yearcent	0.9842	0.9613	1.00765	yearcent	0.9888	0.96616	1.01198	yearcent	0.99115	0.97342	1.0092	yearcent	0.9813	0.9691	0.9937	yearcent	0.9859	0.89982	1.08
EczemaYorN	1.191	0.978	1.45023	EczemaYorN	1.1442	0.8947	1.46336	**EczemaYorN**	**1.2176**	**1.0307**	**1.438**	**EczemaYorN**	**1.201**	**1.046**	**1.378**	EczemaYorN	0.89607	0.37104	2.164
GasStoveYesNo	1.0474	0.8528	1.28632	GasStoveYesNo	0.8966	0.71391	1.12609	GasStoveYesNo	0.89802	0.75977	1.0614	GasStoveYesNo	1.0934	0.9744	1.227	GasStoveYesNo	0.93155	0.3731	2.326
cockroach2	1.4822	0.8138	2.6995	cockroach2	1.2689	0.93597	1.72034	cockroach2	1.26267	0.98471	1.6191	**cockroach2**	**1.359**	**1.18**	**1.565**	cockroach2	1.6262	0.34923	7.572
Rodent	1.1903	0.8163	1.73584	Rodent	1.9805	0.90568	4.33095	Rodent	0.86901	0.45361	1.6648	Rodent	1.0163	0.6908	1.4952	Rodent	1.548	0.08087	29.63
uc	1.177	0.8865	1.56276	**uc**	**2.051**	**1.1**	**3.8232**	uc	1.20497	0.80781	1.7974	uc	1.3393	0.8893	2.0169	uc	2.77082	0.82714	9.282
up	**1.286**	**1.023**	**1.6173**	up	1.5448	0.82253	2.90141	up	1.27127	0.83411	1.9376	up	1.3399	0.8702	2.0633	up	2.07184	0.69635	6.164
rur	0.9771	0.743	1.28483	rur	1.3415	0.57245	3.14385	rur	1.37229	0.67174	2.8034	rur	1.2596	0.6417	2.4724	rur	3.08038	0.61655	15.39

Private																				
Cauc (n ~ 10700)	**OR**	**95% CI**		**Hisp (n ~ 960)**	**OR**	**95% CI**		**AA (n ~ 1970)**	**OR**	**95% CI**		**PR (n ~ 1700)**	**OR**	**95% CI**		**Asian (n ~ 600)**	**OR**	**95% CI**	
Gender	1.0508	0.962	1.14771	Gender	1.0483	0.78295	1.40357	Gender	1.03811	0.84405	1.2768	Gender	0.9785	0.7877	1.2157	Gender	1.00938	0.68171	1.495
FamilyHx	**1.349**	**1.228**	**1.4811**	FamilyHx	1.2745	0.90572	1.79334	**FamilyHx**	**1.2938**	**1.0263**	**1.631**	FamilyHx	1.1505	0.8327	1.5896	FamilyHx	1.02239	0.68424	1.528
Dog	0.9732	0.891	1.06291	Dog	0.8529	0.6108	1.19107	Dog	0.86786	0.66485	1.1329	Dog	0.9823	0.7689	1.2549	Dog	0.66614	0.36888	1.203
Cat	1.0061	0.9165	1.1044	Cat	0.8269	0.55176	1.23932	Cat	0.955	0.66931	1.3626	Cat	0.8174	0.5781	1.1558	Cat	1.33119	0.6533	2.713
STSE	**1.246**	**1.093**	**1.4195**	STSE	1.2713	0.83942	1.92534	STSE	1.26318	0.96415	1.655	STSE	1.1277	0.8568	1.4842	STSE	1.57175	0.80536	3.067
agecent	**0.974**	**0.965**	**0.983**	agecent	0.9987	0.96704	1.03129	agecent	0.97925	0.95874	1.0002	agecent	0.9842	0.9616	1.0073	**agecent**	**0.9422**	**0.8976**	**0.989**
yearcent	0.9934	0.9816	1.00531	**yearcent**	**0.958**	**0.9192**	**0.9985**	yearcent	0.99957	0.97076	1.0292	yearcent	0.9695	0.9397	1.0002	**yearcent**	**0.9237**	**0.874**	**0.976**
EczemaYorN	**1.169**	**1.045**	**1.3084**	EczemaYorN	1.2516	0.87336	1.79356	EczemaYorN	1.10104	0.87693	1.3824	EczemaYorN	1.2208	0.9389	1.5872	EczemaYorN	1.30135	0.84423	2.006
GasStoveYesNo	0.9717	0.8608	1.09687	GasStoveYesNo	1.1088	0.76927	1.59827	GasStoveYesNo	1.08495	0.8632	1.3637	GasStoveYesNo	0.954	0.7525	1.2094	GasStoveYesNo	1.11265	0.68014	1.82
cockroach2	1.2071	0.7324	1.98967	cockroach2	0.9269	0.42917	2.00203	cockroach2	1.12311	0.66449	1.8983	cockroach2	1.4571	0.9915	2.1412	cockroach2	1.12621	0.26154	4.85
Rodent	0.8596	0.7009	1.05431	Rodent	0.7027	0.25348	1.94827	Rodent	1.57016	0.66869	3.6869	Rodent	1.4834	0.7091	3.1032	Rodent	3.34046	0.46611	23.94
uc	**1.411**	**1.156**	**1.7222**	uc	1.3908	0.89289	2.16638	uc	0.95768	0.69549	1.3187	uc	1.2723	0.8287	1.9531	uc	1.25954	0.56695	2.798
up	**1.142**	**1.034**	**1.2612**	up	1.3645	0.90637	2.05409	up	1.02455	0.74651	1.4062	up	1.2635	0.8098	1.9713	**up**	**1.5676**	**1.0219**	**2.405**
rur	**1.159**	**1.014**	**1.3244**	rur	1.4846	0.76382	2.88546	rur	1.33125	0.65078	2.7233	rur	1.2159	0.4878	3.0309	rur	1.29911	0.59949	2.815