Is Disparity in Asthma among Californians due to Higher Pollution Exposures, Greater Vulnerability, or Both?

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Abstract

This study addresses the research question: Is the disproportionate burden of asthma or asthma-like symptoms among low socioeconomic status individuals related to greater pollutant exposures, greater vulnerabilities, or both? Using Geographic Information System (GIS) software, we linked California Health Interview Survey (CHIS) 2003 respondents' residential addresses to government air monitoring stations for O_3, PM_{10}, $PM_{2.5}$, and NO_2. We calculated annual pollutant averages and days exceeding air quality standards and assessed traffic density and residential distance to roadways. Higher exposures were estimated for low income and racial/ethnic minority respondents for NO_2, PM_{10}, and $PM_{2.5,}$ but not for O_3. Among adults, we observed linear increases in asthma outcomes, such as daily/weekly symptoms, asthma attacks, daily medication use, and asthma-related work absences and emergency department visits with increasing annual average pollutant concentrations. Among children, daily asthma medication use and school/day care absences were associated with increased annual average NO_2 concentration. Similar positive associations were observed between O_3, PM_{10}, and $PM_{2.5}$ exceedance days and asthma outcomes, mainly for adults. When adjusting for confounders or modifiers, associations between pollutants and asthma outcomes persisted. Notably, racial/ethnic minority and low income respondents had greater increases in adverse asthma outcomes for similar increases in NO_2 and PM_{10} exposures.

Executive Summary

Background

Children, the elderly (Babey, Hastert et al. 2007), racial/ethnic minorities (Meng, Babey et al. 2007), and low-income Californians (Babey, Hastert et al. 2007) suffer disproportionately from asthma burdens and asthma-like symptoms. Linking air pollutant data from ambient monitors and traffic data with California Health Interview Survey (CHIS) 2003 data, this study tested the following hypotheses: 1) Vulnerable sub-populations in California (e.g., racial/ethnic minorities and low-income individuals) have higher exposures to air pollution; 2) Individuals with asthma or asthma-like symptoms exposed to higher levels of air pollution are more likely to report adverse health outcomes; 3) Air pollution exposures, low socioeconomic status (SES), and certain vulnerability factors exert independent adverse effects on individuals with asthma or asthma-like symptoms; and 4) Higher pollutant exposures interact with vulnerability factors, resulting in greater air pollution impacts on asthma in vulnerable sub-populations.

Methods

We conducted a cross-sectional study linking California Health Interview Survey (CHIS) 2003 data to existing air pollutant and traffic data. We focused our analyses on CHIS 2003 adult respondents ages 18 or older and child respondents ages 0-17 with self-or caregiver-reported lifetime asthma (N=5,620 adults and 1,889 children), defined as physician-diagnosed asthma, specifically distinguishing between those with current asthma (N=3,587 adults and 1,224 children) and those with asthma-like symptoms (N=4,413 adults and 1,109 children). Respondents living at their current addresses or neighborhoods for ≥9 months were included. Using Geographic Information System (GIS) software, we linked respondents' residential addresses to nearby air monitoring stations measuring O_3, PM_{10}, $PM_{2.5}$, and/or NO_2. We calculated annual pollutant averages for the 12-month period prior to respondents' interview dates. Additionally, we calculated the number of federal/state exceedance days for pollutant concentrations and assessed traffic density and distance from residence to roadways as proxies for traffic exposure based on residential address. We performed logistic regression analyses for respondents with asthma or asthma-like symptoms, separately for children and adults. We also conducted pollutant-outcome analyses adjusting for potential confounders related to vulnerability. Interaction terms were used to evaluate increased vulnerability to pollutants among sub-populations. We performed sensitivity analyses on length of residence, employment status and distance from pollutant monitors.

Results

We observed disparities in exposure to air pollutants by income and race/ethnicity among Californians with current asthma. Adults and children with current asthma living below 200% of the federal poverty level (FPL) had higher annual average concentrations for NO_2, PM_{10}, and $PM_{2.5}$ than those living at or above 400% of the FPL. Latino and African American adults and children had higher $PM_{2.5}$ annual averages than whites; Latino and Asian/Pacific Islander children had higher NO_2 annual averages than white children. However, white adults and children had higher exposures to O_3 than Latinos, African Americans, and Asian/Pacific Islanders. Similar exposure disparities were seen for respondents with asthma-like symptoms.

We observed positive associations between increased annual average pollutant concentrations for O_3, PM_{10}, and $PM_{2.5}$ and adverse asthma outcomes among adults, such as frequent asthma symptoms (daily/weekly symptoms), asthma attacks or episodes, use of daily medication to control asthma, work absences, and asthma-related emergency department (ED) visits. Among children, use of daily asthma medication and missing 2 or more days of school/day care were associated with higher exposures to NO_2. We also observed positive associations between asthma outcomes and the number of federal or state exceedance days for O_3, $PM_{2.5}$ and PM_{10}. In adults with asthma-like symptoms, O_3, PM_{10}, and $PM_{2.5}$ increases were associated with increased odds of asthma-like outcomes, and among children, O_3 and NO_2 were associated with increased asthma-like outcomes. We detected very few associations between traffic density and distance to roadway and asthma or asthma-like outcomes.

When adjusting for vulnerability factors, such as access to care, risk behaviors, asthma severity and indoor triggers, positive associations between criteria pollutants and asthma outcomes persisted, as did positive associations between asthma outcomes and belonging to minority or low income sub-populations. Having heart disease and having adult onset asthma independently increased odds for visiting the ED and using daily asthma medication among those with current asthma. Notably, interaction effects were observed between criteria pollutant exposure and race/ethnicity. Specifically, African American and Asian/PI/other adults had a greater increase in odds of missing two or more days of work due to asthma compared to white adults with the same increase in annual average NO_2. African American adults also had greater increases in experiencing daily/weekly asthma symptoms for the same increase in NO_2. Compared to white children, American Indian/Alaska Native and Asian/PI/other children had a greater increase in experiencing daily/weekly asthma symptoms for the same increase in NO_2. Latino children had a greater increase in using daily asthma medication for the same increase in PM_{10}, and African-American and Asian/PI/other children had greater increases in daily/weekly symptoms than white children for a comparable increase in PM_{10}. We also found that children living below 200% of the FPL had a greater increase ED visits compared to those living at or above 400% of the FPL for the same increase in NO_2.

Conclusions

In conclusion, we observed disparities in exposure to air pollutants by federal poverty level and race/ethnicity among Californians with current asthma. In general, higher annual average exposures were observed for lower income groups and racial/ethnic minorities for NO_2, PM_{10}, and $PM_{2.5}$. We observed linear increases in odds of adverse asthma outcomes with increasing annual average pollutant concentrations for O_3, PM_{10}, and $PM_{2.5}$ among adults and NO_2 among children with current asthma. We also observed associations with the number of days exceeding federal or state standards for O_3, PM_{10}, and $PM_{2.5}$. Similarly, in respondents with asthma-like symptoms, positive associations were observed between asthma-like symptoms and annual air pollutant averages and exceedance measures. When adjusting for potential confounders, pollutant associations for O_3, PM_{10}, and $PM_{2.5}$ remained. Novel findings include interaction effects for race/ethnicity and household federal poverty level with annual average pollutant exposures for NO_2 and PM_{10}, suggesting that racial/ethnic minority and low-income groups have greater increases in adverse asthma outcomes at the same level of increase in exposures.

These results provide a more comprehensive understanding of the impact of air pollution on Californians suffering from asthma and asthma-like symptoms and indicate that current air quality in California needs to be further improved in order to protect California residents, especially those in vulnerable sub-populations.

I. INTRODUCTION

Scope and Purpose

In October 2003, the California Air Resources Board (CARB) developed a Vulnerable Population Research Program that aims to protect all California residents, particularly individuals considered especially at risk to the adverse effects of air pollution. For the first time, low-income neighborhoods and communities of color were designated as vulnerable sub-populations, in addition to children, the elderly, people with preexisting cardiovascular and/or pulmonary disease, and individuals who spend a large amount of time outdoors. This research was designed to provide much needed information on the effects of long-term air pollution exposure on severe asthma and asthma-like symptoms in vulnerable populations.

According to the estimates from the 2003 California Health Interview Survey (CHIS 2003), 4.5 million Californians suffer from asthma and an additional 3.4 million Californians suffer from asthma-like symptoms (Babey, Meng et al. 2006). Although asthma cannot be cured, most individuals with asthma can become symptom-free by avoiding or controlling environmental triggers and by taking proper medications. However, children, the elderly (Babey, Hastert et al. 2007), racial/ethnic minorities (Meng, Babey et al. 2007), and low-income Californians (Babey, Hastert et al. 2007) suffer disproportionately from asthma and asthma-like symptoms. Previous studies also indicate some sub-populations are more affected by pollutants due to increased susceptibility or higher exposures. For instance, children are especially susceptible to the damaging effects of O_3 in part because their lungs are still developing , which makes them more sensitive to pollutant damage (Gilliland, McConnell et al. 1999). Minorities may be more affected due to differential exposure to air pollution and vulnerability (Clark, Brown et al. 1999; Ostro, Lipsett et al. 2001; Mortimer, Neas et al. 2002; Perera, Illman et al. 2002). More studies need to be conducted on other vulnerable populations, such as those with low socioeconomic status (O'Neill, Jerrett et al. 2003).

The overall goal of the proposed project was to test the hypotheses whether the disproportionate asthma burden among these California sub-populations (e.g., low-income and ethnic minorities) is related to higher exposure to air pollutants, greater vulnerability due to low socioeconomic status (SES) related factors, or both. Here we defined "vulnerability" based on a "triple-jeopardy" theory (Jerrett, Burnett et al. 2001; Levy, Greco et al. 2002), namely that: 1) certain sub-populations (e.g., groups with low SES) are exposed to higher levels of air pollution; 2) these individuals already have poorer health due to social determinants, such as poverty, lack of adequate health care, and psychosocial stress; and 3) this combination of higher air pollution exposures and poorer baseline health interacts, resulting in greater air pollution impacts on asthma in these vulnerable groups. No routine asthma surveillance system, such as a registry, exists in California except for mortality statistics and hospital discharge/emergency department (ED) visit data. CHIS data makes it possible, for the first time, to relate exposure to health outcome data for a large number of people with asthma (larger than the National Health Interview Survey (NHIS)). The CHIS sample is representative of California's non-institutionalized population and asks many standard health questions from the NHIS. Additionally, CHIS provides a unique opportunity to study the adverse effects of air pollution because it collects information on residential address and duration of residence in the same neighborhood.

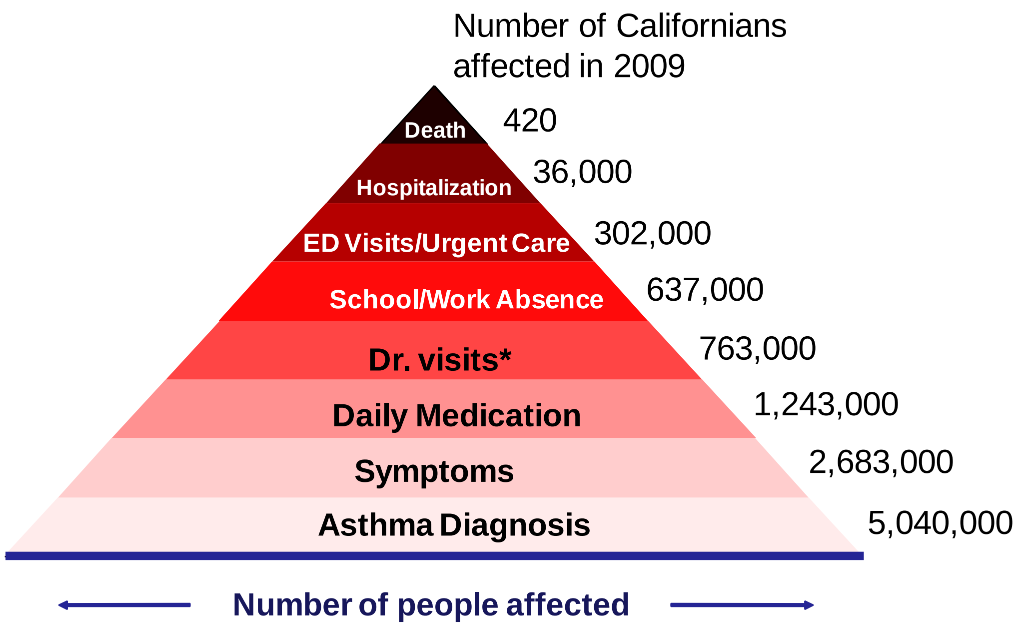
The proposed objectives of this study were to: 1) characterize air pollution exposures by linking geocoded CHIS 2003 respondent residence locations to appropriate air monitoring stations and calculating annual average air pollutant concentrations (O_3, $PM_{10,}$ $PM_{2.5}$, and NO_2) from the nearest monitoring station (e.g., 10 km) or interpolated pollutant concentrations for a maximum of three monitoring stations within a specified radius (e.g., 50 km), and exceedance frequencies (e.g., number of days or hours above a certain cut-off point); 2) develop GIS-based residential annual traffic density and distance to major roadways/freeways measures using data from the California Department of Transportation (Caltrans) for each CHIS 2003 respondent; 3) identify sub-populations (e.g., low-income, children, the elderly, rural/urban residents, and ethnic minorities) that have higher exposures to a single pollutant or pollutant mixes, and/or potentially greater vulnerability to these exposures; 4) determine whether the disproportionate burden of asthma or asthma-like symptoms among low SES individuals is associated with greater pollutant exposures, greater vulnerabilities, or both, including evaluating factors that contribute to or modify the impact of air pollution on these sub-populations; and 5) develop a report and disseminate the results to policy makers, public health and environmental agencies, community-based organizations, and the public.

Previous Studies on Asthma Exacerbations and Pollutant Exposures among Vulnerable Populations

Pollutant Impacts on Asthma

A wide-ranging spectrum of negative heath effects related to air pollution was recognized by the American Thoracic Society. These effects are ordered in the pyramid below according to their frequency of occurrence within the population of California (Figure 1). Though previous studies have mostly focused on the more extreme outcomes, such as hospitalizations and deaths, these outcomes have impacted a relatively small fraction of the population. When we consider that the ratio of asthma diagnoses to asthma-related deaths is about 10,000 to 1, it is clear that these less severe health effects are equally in need of attention because of the large of number of people they affect. As noted in Figure 1, an estimated 5.08 million people in the state of California live with an asthma diagnosis based on CHIS 2009 data. Of those, 2.7 million were affected by asthma-related symptoms and 1.2 million had to take a daily asthma medication; 637,000 missed school or work due to asthma, and 763,000 visited the doctor 9 or more times for any reason. Emergency department/urgent care visits due to asthma were reported by over 302,000 of those with an asthma diagnosis; 36,000 of those were hospitalized (data from the Office of Statewide Health Planning and Development, California), and 420 died in 2009 (data from the Department of Public Health, California*)*. This study provides a unique and much needed opportunity to assess the spectrum of the impact of air pollution on all people with asthma or asthma-like symptoms in California.

Figure 1: Pyramid of Asthma Burden in California (Adapted from the American Thoracic Society)



* 9 or more Dr. visits, not necessarily asthma-related

Data Sources: State of California, Department of Public Health, Death Records; Office of Statewide Health Planning and Development, CHIS 2009

Over the past few decades, studies have linked ozone (O_3), nitrogen dioxide (NO_2), and particulate matter (PM) exposure to negative respiratory health outcomes, including reduced lung function, respiratory inflammation, and lung congestion. In addition to these outcomes, studies connect greater air pollutant exposure to increases in asthma attacks and other asthma-related negative health events, such as ED/hospital visits, medication use, and absences from school. The following is a brief summary of the existing literature.

Increased Asthma Symptoms and Medication Use: Exposure to criteria pollutants is associated with increases in asthma symptoms and medication use. A study by Thurston and Lippmann observing asthma outcomes in children with moderate to severe asthma attending summer camp found that the children had 40% more asthma symptoms when O_3 levels increased from an average O_3 level of 84 ppb to 160 ppb (Thurston, Lippmann et al. 1997). Additionally, elevations in O_3 levels have been associated with increases in medication use among children (Gent, Triche et al. 2003; Yang, Holz et al. 2005).

Moreover, in panel studies among children with asthma, increased PM exposure was associated with increases in asthma symptoms (Ward and Ayres 2004). A study based in Southern California found that as exposure to PM increased, children that exhibited the most symptoms at baseline and were not taking asthma medication were most likely to experience increased asthma symptoms (Delfino, Zeiger et al. 1998). Similar associations between PM and asthma medication use have been noted by others (Pope, Dockery et al. 1991; Slaughter, Lumley et al. 2003; Kerkhof, Postma et al. 2010).

Similarly, studies indicated a positive relationship between NO_2 exposure and increases in both asthma symptoms (Mortimer, Neas et al. 2002; Delfino, Gong et al. 2003; McConnell, Berhane et al. 2003; Gauderman, Avol et al. 2005; Schildcrout, Sheppard et al. 2006) and medication use (Gauderman, Avol et al. 2005; Schildcrout, Sheppard et al. 2006). For example, in a study of 208 children in 10 cities in Southern California, children were twice as likely to take asthma medication with increasing NO_2 exposure (Gauderman, Avol et al. 2005).

Increased School Absences: Increases in criteria pollutant levels coincide with increases in students' absence from school. A study performed in southern California found that a short-term, 20 ppb spike in O_3 levels was associated with an 82.9% increase in student absences due to respiratory illness (Gilliland, Berhane et al. 2001). Likewise, increased PM and NO_2 levels were associated with increases in school absences among inner city children with asthma from 7 cities across the U.S. (O'Connor, Neas et al. 2008).

Increased Emergency Department (ED) visits/Hospitalizations: Increases in exposure to criteria pollutants, such as O_3, have been linked to increases in ED visits and hospitalizations due to asthma-related events (Romieu, Meneses et al. 1995; Anderson, Ponce de Leon et al. 1998; Tolbert, Mulholland et al. 2000; Lin, Liu et al. 2008; Moore, Neugebauer et al. 2008; Meng, Rull et al. 2010). White et. al compared the number of ED visits due to respiratory problems to fluctuations in O_3 levels and noted a 37% increase in the number of visits to the ED subsequent to O_3 level increases (White, Etzel et al. 1994). The direct relationship between O_3 and ED visits/hospitalizations has been documented in both directions; as O_3 levels decrease, so do the number of asthma-related hospital visits. Following a change in traffic patterns due to the 1996 Summer Olympics and the resulting decrease in O_3 exposure, Atlanta children experienced a 42% decline in health care utilization for asthma (Friedman, Powell et al. 2001).

Furthermore, the number of ED visits has been shown to escalate as PM exposure increases. In a study among inner city children in Seattle, an 11% increase in asthma-related ED visits was observed as exposure to $PM_{2.5}$ increased (Norris, YoungPong et al. 1999). An association between daily PM2.5 and ED visits for asthma at lag days 2 and 3 was observed in the greater Tacoma, Washington area. The relative risk for lag day 2 was 1.04 and for lag day 3 was 1.03(Mar, Koenig et al. 2010).

Studies also demonstrated a positive relationship between NO_2 and ED visits/hospitalizations (Lin, Chen et al. 2003; Barnett, Williams et al. 2005; Villeneuve, Chen et al. 2007). Among them, a study in Barcelona, Spain, documented increases in ED visits corresponding with NO_2 exposure in both winter and summer months (Castellsague, Sunyer et al. 1995).

Vulnerable Populations

Air pollution affects people in all groups, spanning all ages, races, and income levels; however, the burden of the air pollution effects is not equally shared. Some sub-populations, such as low income and/or minority groups, children, and the elderly, have been shown to have higher exposures or increased risk for adverse asthma outcomes due to air pollution compared to the rest of the population.

Children: Children's physiology and activity patterns leave them more susceptible to the negative effects of air pollutants on their respiratory health (Schwartz 2004; Trasande and Thurston 2005; Bateson and Schwartz 2008). Children's lungs continue developing from birth to adolescence. Since their lungs are still developing, their respiratory extracellular lining fluid (RELF) is not as effective at protecting against the damaging effects of air pollutant penetration as the lining in adult lungs (Gilliland, McConnell et al. 1999). They are more receptive and responsive to exposures because the surface area of their airways is smaller. Additionally, children often breath through their mouths, instead of their noses, so fewer air pollution particles are filtered out before reaching the lungs (Bateson and Schwartz 2008), compounded by the fact that children simply breathe more than adults. Higher breathing rates among children means they take in more air, and therefore potentially more air pollutants, than adults per unit of body weight (Arcus-Arth and Blaisdell 2007). In addition to physiological susceptibility, children more frequently come in contact with air pollution because they participate in outdoor activities. Children usually engage in over 5 times the amount of outdoor physical activity as adults (Wiley, Robinson et al. 1991; Wiley, Robinson et al. 1991) and do so during high O_3 periods, such as during the afternoon or summer.

Elderly: Though studies observing the effects of air pollution on asthma in the adult population are relatively rare, some studies have suggested that the elderly may be more susceptible to the effects of air pollutants. This vulnerability may be due to greater lifetime exposure and weaker immune system responses (Sandstrom, Frew et al. 2003), though studies also suggest that comorbidities, especially cardiovascular and respiratory diseases, may also contribute to increases in negative health outcomes related to asthma among the elderly population (Gouveia and Fletcher 2000; Aga, Samoli et al. 2003; Anderson, Atkinson et al. 2003; Sandstrom, Frew et al. 2003; Filleul, Rondeau et al. 2004; Gauderman, Avol et al. 2004; Meng, Wilhelm et al. 2007).

Populations with Low Socioeconomic Status: Populations with low SES have been shown to be more affected by pollutants due to their greater vulnerability or higher exposures (Gwynn and Thurston 2001; Finkelstein, Jerrett et al. 2003; Meng, Wilhelm et al. 2008; Grineski, Staniswalis et al. 2010). Several studies reported disparities in pollution exposures by SES. For instance in California, census block groups in the lowest quartile of median family income were three times more likely to have high-traffic density than block groups in the highest income quartile (Gunier, Hertz et al. 2003). Children of color were also more likely to live in high traffic areas than white children (Gunier, Hertz et al. 2003). Studies in other states have reported low SES individuals are more likely to be exposed to O_3 (Korc 1996) and other pollutants (Neumann, Forman et al. 1998). Additionally, there is evidence that low SES populations are more affected than high SES populations when exposed to the same levels of air pollution. In Toronto, Canada, the risks of asthma-related physician visits for the low socioeconomic group were significantly greater than those for the high socioeconomic group when the two groups had comparable levels of SO_2 and $PM_{2.5}$ exposure (Burra, Moineddin et al. 2009). The high prevalence of frequent asthma symptoms among low income Californians has also been shown to be related to both higher traffic-related pollution exposures and increased vulnerability due to differences in overall health status and access to care; therefore, those in poverty appeared to be more strongly affected by heavy traffic near their residences than those above poverty (Meng, Wilhelm et al. 2008).

Minorities: Gwynn and Thurston (2001) also examined whether racial minorities are more adversely affected by ambient air pollution than their white counterparts and assessed the contribution of socioeconomic status to observed racial differences in pollution effects. They found attributable risks from air pollution (in terms of excess admissions per day per million persons) were larger for minorities than whites. However, when insurance status was used as an indicator of socioeconomic/health coverage status, higher relative risks were indicated for the poor/working poor (i.e., those on Medicaid and the uninsured) than for those who were economically better off (i.e., the privately insured), even among non-Hispanic whites (Gwynn and Thurston 2001).

Study Hypotheses

The previous studies on asthma-related effects tend to focus on the impact of short-term (days or weeks) pollutant exposures on mortality and hospitalizations (Schwartz, Slater et al. 1993; Anderson, Ponce de Leon et al. 1998; Delfino, Murphy-Moulton et al. 1998; Sunyer, Basagana et al. 2002). However, death and hospitalizations represent just the tip of the iceberg of the overall asthma burden. More studies are needed to examine many outcome measures that affect a much larger population, such as ED visits, medication use, frequency of asthma symptoms, and school/work days missed due to asthma. Also, most of the studies have focused on the air pollution impacts on children; limited numbers of studies are available on the adult population. Previous studies indicate that vulnerable subpopulations, such as low-income and communities of color in California, have higher exposures to air pollution. Studies have also shown that children, the elderly (Babey, Hastert et al. 2007), racial/ethnic minorities (Meng, Babey et al. 2007), and low-income Californians (Babey, Hastert et al. 2007) suffer disproportionately from asthma and asthma-like symptoms. More studies are needed to examine whether the disproportionate asthma burden among these subpopulations is related to higher exposure to air pollutants, greater vulnerability due to low socioeconomic status and associated factors such as compromised health status, poor access to care, and behavioral risk factors, or to a combination of these factors. This study was designed to address the above mentioned gaps in the literature, and specifically to **provide much needed information on the effects of long-term air pollution exposure on asthma symptoms in especially vulnerable sub-populations, such as children, the elderly, racial/ethnic minorities, and low-income Californians.** As mentioned above, we defined "vulnerability" based on a "triple-jeopardy" theory (Jerrett, Burnett et al. 2001; Levy, Greco et al. 2002). Our specific study hypotheses were:

1) Vulnerable sub-populations in California (e.g., racial/ethnic minorities and low-income individuals) have higher exposures to air pollution;
2) **Individuals with asthma** exposed to higher levels of air pollution are more likely to report adverse asthma outcomes, such as: asthma attacks or episodes, asthma emergency department (ED) visits, use of daily medication to control asthma, school or work absences, and daily/weekly asthma symptoms. **Individuals with asthma-like symptoms** (defined here as individuals without physician-diagnosed asthma but reported wheezing) and exposed to higher levels of air pollution are more likely to report: wheezing or whistling sound in the chest, attacks of wheezing or whistling, seeking medical care for such symptoms, and work/school days missed due to such symptoms;
3) Air pollution exposures, low socioeconomic status (SES), and certain "vulnerability factors" associated with low SES, exert independent adverse effects on individuals with asthma or asthma-like symptoms. The vulnerability factors examined were: **co-morbidity** (such as diabetes or heart disease); **access to care** (health insurance status, usual source of care); **disease management/asthma severity** (taking daily medication to

control asthma, receiving an asthma management plan); **health behaviors** (being overweight/obese, smoking, walking outdoor, engaging in physical activity); **exposure to indoor triggers** (environmental tobacco smoke and indoor allergens, cockroaches, dogs and cats); and **housing conditions** (single family dwelling or apartment, crowding); and

4) Higher pollutant exposures interact with these vulnerability factors resulting in greater air pollution impacts on asthma in vulnerable sub-populations (racial/ethnic minorities, low-income individuals).

Background on the California Health Interview Survey (CHIS) 2003

CHIS is a population-based random-digit dial telephone survey of California's population that is conducted every two years. First conducted in 2001, CHIS is the largest health survey ever conducted in any state and one of the largest health surveys in the nation. CHIS is a collaborative project of the UCLA Center for Health Policy Research, the California Department of Health Services, and the Public Health Institute. CHIS collects extensive information for all age groups on health status, health conditions, health-related behaviors, health insurance coverage, access to health care services, and other health and development issues. The goal is to provide health planners, policymakers, state, county and city health agencies, and community organizations with information on the health and health care needs facing California's diverse population.

CHIS provides a representative sample of the state's non-institutionalized population. The CHIS sample is designed to meet two broad objectives: 1) provide local-level estimates for counties with populations of 100,000 or more; and 2) provide statewide estimates for California's overall population and its larger racial/ethnic groups, as well as for several smaller ethnic groups. To address the first objective, the sample was allocated by large counties (those with a population over 100,000) and aggregates of smaller counties (those with a population less than 100,000) with supplemental samples of selected populations and cities. To accomplish the second objective — assuring adequate sample sizes for larger racial/ethnic groups and some smaller ones, CHIS 2001 used two strategies. First, sufficient samples were allocated to the larger urban counties in which the populations of color disproportionately reside to generate adequate samples for major ethnic groups of color. Second, supplemental samples were designed to improve the sample size and precision of the estimates for specific ethnic groups. To capture the rich diversity of the California population, interviews were conducted in six languages: English, Spanish, Chinese (Mandarin and Cantonese dialects), Vietnamese, Korean, and Khmer (Cambodian). These languages were chosen based on research that identified these as the languages that would cover the largest number of Californians who did not speak English or did not speak English well enough to participate in an interview. As a result, CHIS allows us to study disparities in health status among California's most-represented racial and ethnic groups.

CHIS had a multi-stage sample design. First, the state was divided into 41 geographic sampling strata, including 33 single-county strata and 8 groups that included the 25 other counties with small population sizes. Second, within each geographic stratum, households were selected through random-digit dial (RDD), and within each household, an adult (age 18 and over) respondent was randomly selected. In addition, in those households with children (under age 12) or adolescents (ages 12-17) associated with the sampled adult, one child and one adolescent were randomly sampled, so up to three interviews could have been completed in each sampled household. The sampled adult was interviewed, and the parent or guardian most knowledgeable about the health and care of the sampled child was interviewed. The sampled adolescent responded for him or herself, but only after a parent or guardian gave permission for the interview. Adjustment factors for the selection mechanisms have been incorporated into the data's sample weights.

CHIS collects information on major chronic diseases, such as asthma, heart disease, hypertension, cancer, arthritis and diabetes. Since many chronic diseases have multiple causes and are influenced by many factors, the development and control of these chronic diseases can be very complex. Therefore, it is important to examine the relationship between disease and exposure to hazards after controlling for confounding factors. For example, control of asthma exacerbations may not only relate to reducing exposures to environmental triggers, but also to improving access to timely and quality healthcare. In this regard, CHIS has advantages over many administrative data sources such as vital statistics, hospital discharge data, cancer registry data or claim data. These administrative data sets usually lack detailed information related to socioeconomic status, access to healthcare, and health risk behaviors. However, CHIS 2001 collected many measures for health outcomes, access to care, and socio-demographic information. Beginning with CHIS 2003, CHIS has collected residential address information for respondents. This geographic information allows us to link CHIS respondents' data to the air pollution data collected at fixed monitoring stations, as well as traffic data or other environmental hazard data. This linkage also allows us to assess the health effects of exposure to environmental hazards. These kinds of linkages are usually not possible or meaningful for NHIS and BRFSS since these surveys are not designed to provide information below the state level. Hospital Discharge data does provide patients' zip code information. However, this data source only contains information about people admitted to the hospital and is not a source of information on disease prevalence.

Westat, a private firm that specializes in statistical research and large-scale sample surveys, conducted the CHIS 2003 data collection. The overall response rate for CHIS 2003 is a composite of the screener completion rate (i.e., success in introducing the survey to a household and randomly selecting an adult to be interviewed), and the extended interview completion rate (i.e., success in getting the selected person to complete the full interview). In 2003, the screener completion rate was 55.9 percent, and the rate was higher for those households that could be sent a letter introducing them to the survey in advance. The extended interview completion rate was 60.0 percent for the adult survey. The CHIS response rate is comparable to response rates of other scientific telephone surveys in California, such as the California Behavioral Risk Factor Surveillance System (BRFSS) survey.

In summary, CHIS data provide the first-ever opportunity to provide population-based information examining the association between exposure to air pollution and adverse respiratory health outcomes while also incorporating socioeconomic status, disease management/asthma severity , risk factors such as smoking and obesity, and access to care. Such an effort would usually be very time-consuming and costly. The availability of CHIS data made this type of study possible with relatively modest means in terms of time and resources.

II. MATERIALS AND METHODS

Study Design

To investigate the effects of air pollution on those with asthma and asthma-like symptoms in California and to identify potentially vulnerable subgroups, we conducted a cross-sectional study linking California Health Interview Survey (CHIS) 2003 data to existing air pollutant and traffic data. First, we selected CHIS 2003 respondents with current asthma and those not diagnosed with asthma who reported experiencing asthma-like symptoms. We linked these respondents' residential addresses to the nearest government air monitoring station for each of four criteria pollutants (O_3, PM_{10}, $PM_{2.5}$, and NO_2). We then calculated annual pollutant averages for the 12-month period prior to respondents' CHIS interview dates. We also assessed traffic density and distance to roadways as proxies for traffic exposure. We performed univariate and multivariate logistic regression analyses to examine associations between air pollution and asthma outcomes. Interaction terms were used to evaluate increased vulnerability to pollutants among sub-populations.

Study Population

CHIS 2003 interviews were conducted from August 2003 to February 2004. CHIS 2003 collected information on approximately 54,500 non-institutionalized Californians, including 12,500 children (<18 years of age). Respondents were asked if they had ever been told they have asthma by a doctor and at what age. In addition to asking about asthma outcomes, CHIS respondents never diagnosed with asthma were asked if they experienced any wheezing or whistling sound in their chests in the past 12 months. About 15% (n=1,889) of children (<18 years of age) and 12% (n=5,620) of adults reported a physician diagnosis of asthma at some point in their lives, here defined as "lifetime asthma" (Table 1). Among those with a lifetime asthma diagnosis, 4,811 (3,587 adults and 1,224 children) had "current asthma", defined as reporting that they still have asthma and/or that they had an asthma attack in the year prior to their CHIS interview. An additional 10% of Californians not reporting to ever have been diagnosed with asthma (n=5,522, 4,413 adults and 1,109 children) reported experiencing asthma-like symptoms, i.e., wheezing or whistling in the chest in the past year. We restricted our study population to those who lived in the same home or neighborhood for at least 9 months and some analyses were only limited to the respondents with geocodable home addresses . Three hundred and fifteen respondents with current asthma and 442 respondents with asthma-like symptoms were excluded because they did not live in the same neighborhood for at least 9 months. Residential geocodes were based on address (83.8%), nearest cross-streets (4.2%), or zip code (11.9%). For traffic density and distance to roadway analyses, geocodes based on residential zip code were excluded (n=537). For air pollution analyses, only respondents living within 5 miles of an air monitoring station were included to reduce potential exposure misclassification. However, sensitivity analyses were conducted for 3-, 5-, and 10-mile linkage distances.

Table 1. Number of CHIS 2003 adults and children with asthma or asthma-like symptoms

	Adults	Children
Lifetime Asthma	5,620	1,889
≥ 9 months in neighborhood	5,236	1,783
Geocoded by address or nearest cross-street	4,595	1,579
Current Asthma	3,587	1,224
≥ 9 months in neighborhood	3,343	1,153
Geocoded by address or nearest cross-street	2,941	1,018
Asthma-Like Symptoms	4,413	1,109
≥ 9 months in neighborhood	4,129	951
Geocoded by address or nearest cross-street	3,629	833

Measures of Air Pollutant Exposure

Annual Average Air Pollution Concentrations for O_3, PM_{10}, $PM_{2.5}$, and NO_2

Annual air pollutant averages were calculated for the 12-month period prior to each respondent's CHIS interview date by linking respondents to the nearest government air monitoring station within 20 miles of their residential addresses. All mapping work was performed using ESRI ArcGIS software. In cases where residential address was not available, respondents' residential locations were geocoded based on nearest cross streets, and in some cases residential 5-digit zip codes. Pollutant averages were estimated using air pollution data from the CARB 2008 Air Quality Data DVD (Table 2).

Table 2. Description of pollutant averages calculated for CHIS 2003 respondents

Pollutant	Exposure measure
O_3	12-month averages of 8 hour daily maximum values (dlygas.dbf, OZMX8ST))
NO_2	12-month averages of daily (24-hour) averages (calculated using hourly data)
PM_{10} & $PM_{2.5}$	12-month averages of daily (24-hour) averages (most stations have 24-hour averages; for the few stations that measure hourly, we used the CARB calculated 24-hr averages)

For O_3, annual averages were based on daily 8-hr maximums provided by CARB (variable name OZMX8ST). Again, we first estimated monthly averages, requiring at least 50% of daily values to be available (15 daily values/month). Annual averages were then estimated based on monthly averages for subjects who had 12 monthly values available.

For NO_2, we estimated daily (24-hr) averages based on the raw hourly data. To ensure sufficient monitoring data were available, we required at least 50% of hourly values be available per 24-hr period and at least 50% of hourly values be available during 8am-8pm. If these two criteria were not met, we recorded a missing value for the 24-hr average for that day. Then, we averaged the NO_2 24-hr averages for each month, requiring at least 50% of daily values to be available per month, i.e. 15 daily values/month.

Most PM stations recorded 24-hr averages every 6 and 3 days for PM_{10} and $PM_{2.5}$, respectively. For the few stations with hourly PM data, we used CARB's calculated daily (24-hr) averages. For PM_{10}, we required that at least 50% of expected values be available for each monitor frequency, i.e., at least 3 (out of 5) daily values per month for stations that monitored every 6 days and at least 15 daily values per month for stations that monitored every day. For $PM_{2.5}$, we required at least 5 (out of 10) daily values to be available per month for stations that monitored every 3 days and at least 15 daily values per month for stations that monitored every day.

Some PM stations had collocated (multiple) monitors. In these cases, we checked the recorded data for each monitor to determine whether it met the above sufficiency criteria. If both monitors met the criteria, we averaged all available daily measures from both stations for the given month. If only one monitor met the criteria, then we used data from that monitor.

Finally, annual averages were then estimated based on monthly averages for subjects who had 12 monthly values available. For all pollutants, if data did not meet the sufficiency criteria defined above, we searched to see if there was another monitor measuring that pollutant within 20 miles. If a more distant station had more complete data that met the sufficiency criteria, data from that station was used to calculate exposure averages. We generated variables to record: (1) if there was no station available within 20 miles and which station was used to generate the exposure average (i.e., sortid=1 if the closest station was used to create the average, sortid=2 if the next closest station within 20 miles was used, etc). We also recorded the distance to the station used to estimate the average.

We further restricted our study population to individuals residing within a relatively close proximity (5 miles $\approx$ 8 km) to a monitoring station, after sensitivity analyses were conducted for 3-, 5-, and 10-mile linkage distances.

Exceedances of Federal and State Standards

Annual exceedances of federal and state standards for O_3, PM_{10}, $PM_{2.5}$, and NO_2 were calculated for the 12-month period prior to each respondent's CHIS interview date, again linking respondents to the nearest government air monitoring station within 20 miles of their residential addresses (Table 3).

Table 3. List of exceedance exposure measures calculated for CHIS 2003 respondents

Exceedance measure	Description
O_3 1-hr (State)	Number of days in 12-months prior to interview date where 1-hour daily ozone max (OZMAX1HR) >0.09 ppm
O_3 8-hr (State)	Number of days in 12-months prior to interview date where 8-hour daily ozone max (OZMX8ST) >0.070 ppm
O_3 8-hr (Federal)	Number of days in 12-months prior to interview date where 8-hour daily ozone max (OZMX8ST) >0.08 ppm
NO_2 1-hr (State)	Number of days in 12-months prior to interview date where 1-hr daily NO_2 max (NO2MAX1H) >0.18 ppm
PM_{10} 24-hr (State)	Number of days in 12-months prior to interview date where 24-hour average PM_{10} >50 ug/m3
PM_{10} 24-hr (Federal)	Number of days in 12-months prior to interview date where 24-hour average PM_{10} >150 ug/m3
$PM_{2.5}$ 24-hr (federal)	Number of days in 12-months prior to interview date where where 24-hour average $PM_{2.5}$ >35 ug/m3

For NO_2 and O_3, we used 1-hr and 8-hr daily maximum values provided by CARB to estimate number of exceedance days, i.e., days above state and federal standards. For NO_2, the number of exceedance days was counted where NO2MAX1H>0.18 ppm for the state 1-hour standard. There is no equivalent federal standard. Similar to the annual average air pollution averages, we required at least 50% of daily values per month to be available to generate a nonmissing monthly count value. Because almost 100% of the study population had no days exceeding the NO_2 standard, this measure was not used in the analyses.

For O_3, the number of exceedance days was counted where OZMAX1HR>0.09 ppm for the state 1-hr standard. There is no federal 1-hr standard. We also counted exceedance days where OZMX8ST>0.070 ppm for the state 8-hr standard and where OZMX8ST>0.08 ppm for the federal 8-hr standard. Again, we required at least 50% of daily values per month be available. The O_3 federal 8-hr standard was not used in the regression analyses comparing quartiles because more than 25% had a value of 0, resulting in having no < 25^{th} percentile reference group to use.

For PM_{10}, we counted the number of days where 24-hr averages>50 µg/m^3 (state 24-hr standard) and 24-hr average>150 µg/m^3 (federal 24-hr standard), requiring at least 50% of expected values for each monitor frequency (i.e., at least 3 (out of 5) daily values per month for stations that monitored every 6 days and at least 15 daily values per month for stations that monitored every day.

For $PM_{2.5}$, we counted the number of days where 24-hr averages>35 µg/m^3 for the federal 24-hr standard. There is no state 24-hr standard. We required at least 50% of expected values for each monitor frequency (i.e., at least 5 (out of 10) daily values per month for stations that monitored every 3 days and at least 15 daily values per month for stations that monitored every day.

For PM stations with collocated monitors, we checked whether each station met the above sufficiency criteria. If both monitors met the criteria, we averaged available daily measures from both stations for the given month. If only one monitor met the criteria, then we used the data from that monitor.

If data were sufficient, we took the sum of monthly counts to generate final annual exceedance counts for each pollutant. If data did not meet the sufficiency criteria defined above, we searched to see if there was another monitor measuring that pollutant within 20 miles. If a more distant station had more complete data, that station was used to calculate the exceedance value. Again, information was recorded on distance to station and whether the closest or a more distant station was used due to implementation of the sufficiency criteria.

Interpolated Pollutant Concentrations

We originally proposed to interpolate air pollution measurement data from monitoring stations assigned to residential locations in rural areas using inverse distance weighting and a maximum of three monitoring stations for each interpolation. However, even expanding the interpolation radius out to 10 miles, only a small percent of rural subjects (9% (n=48), 21% (n=177), 14% (n=120) and 5% (n=37) for NO_2, O_3, PM_{10} and $PM_{2.5}$, respectively) had more than one monitoring station available to inform such modeling. Since interpolation would not be relevant for ≥80% of the rural subjects, even with a large 10 mile radius, we excluded this exposure modeling method.

Measures of Traffic Exposure

We generated several measures based on distance to and traffic levels on roadways near CHIS respondent homes as proxies for traffic exhaust exposures. We estimated traffic density within 500, 750, and 1000 feet around each subject's home location using Tele Atlas'

Dynamap traffic count data from Spatial Insights Inc., Bethesda, MD. These data were imputed to all road segments in the state based on roadway type. We also calculated the distance from each home to the nearest interstate highway, state highway, and major road using the Tele Atlas Dynamap 2000 roadway map. All work was completed using ESRI's ArcGIS software.

State-wide Imputation of Tele Atlas Traffic Data

We teamed up with Drs. Michael Jerrett and Jason Su at UC Berkeley to use Tele Atlas' Dynamap data (Spatial Insights Inc., Bethesda, MD) to derive a state-wide traffic count map for estimating residential traffic density. We used an imputation method to attribute available measured traffic counts to un-counted road segments in the state. We used Tele Atlas Dynamap 2000 as our roadway map for the imputation because the underlying road network had the most accurate spatial representation when compared to digital orthophotos. The Tele Atlas Dynamap traffic data (in the form of annual average daily traffic or AADT) were combined into a mosaic from individual county files and repeated road segments were removed. Measured traffic counts were available for 2.0% of the road segments in California (56734 out of 2784428 segments) during the period from 1987 to 2005 (Table 4). For the imputation, the median traffic count from measured road segments within a given road category was assigned to un-counted road segments within the same category. The road feature classification codes (FCC) were aggregated into the following seven road categories for the imputation: (1) primary road with limited access (i.e., interstate highway: A1), (2) primary road without limited access (i.e., state highway: A2), (3) secondary and connecting road (i.e., major road: A3), (4) local, neighborhood or rural road (A4), (5) vehicle trail (A5), (6) road ramp (A6), and (7) bicycle, pedestrian trail or drive way (A7).

Table 4. Distribution of traffic volumes for major roadway categories based on Tele Atlas Dynamap traffic data – State of California

Road category[a]	Traffic volume measurements						Tele Atlas data	
	# roads	Minimum	Maximum	Mean	Median	Std	# roads	%
A1	6076	1300	210500	56229.93	46500	40894.38	76286	7.96
A2	3419	210	76000	13154.88	11150	10406.72	44430	7.70
A3	27242	10	239000	12253	10463	9342.19	442460	6.16
A4	19824	1	88680	4003.83	2317	4860.98	1965782	1.01
A5	3	564	2100	1092.67	614	872.73	56049	0.01
A6	158	906	210500	25983.21	14150	32918.15	106883	0.15
A7	12	95	29900	6576.42	1280	10559.1	92538	0.01
Total:	56734						2784428	2.04

[a]A1: Primary highway with limited access; A2: primary road without limited access; A3: secondary and connecting road; A4: local, neighborhood and rural road; A5: vehicular trail; A6: road access ramp; A7: road as other thoroughfare.

Residential Traffic Density

Mapped home locations for CHIS 2003 respondents were then overlaid with the Tele Atlas Dynamap 2000 roadway map containing the imputed traffic count data. We drew 500-, 750-, and 1000-foot buffers around each subject's home location and identified all roadways within these buffers. Similar to Gunier et al.(Gunier, Hertz et al. 2003) and Reynolds et al.(Reynolds, Von Behren et al. 2004), the traffic density value for each subject was estimated by first calculating the Vehicle Meters Traveled (VMT) for each road segment within the buffered area. VMT was estimated by multiplying the AADT value by the corresponding road segment length. Traffic density was then calculated as the sum of the VMT for all road segments in the buffer divided by the area of the buffer, i.e.,

$$TD = \sum(AADT \times L)/A_B,$$

where TD is traffic density (vehicles x meters/day/meters^2), AADT the annual average daily traffic count (vehicles/day), L the length of roadway segment (meters), and A_B the area of the buffer: 500 ft (152.4 m): 72966 m^2; 750 ft (228.6 m): 164173 m^2; 1000 ft (304.8 m): 291864 m^2.

Distance to Roadways

Again using the Tele Atlas Dynamap 2000 roadway map, we also calculated distance from mapped home locations to nearest interstate highways, state highways and major roads. Distance to roadway measures do not rely on the availability of traffic data near respondents' residences and, therefore, can be calculated for respondents without using imputation. Also, freeways and highways may be particularly important exposures for those with respiratory problems, since they have more diesel truck traffic and higher traffic volumes than smaller roads. For these analyses, we determined the distance in meters from subjects' homes to the nearest interstate highway, state highway, and major road (see Table 5 for a description of roadway groupings).

Table 5. Tele Atlas roadway groupings for distance to roadway calculations

Tele Atlas FCC code	Tele Atlas Description	Our grouping
A10	Primary interstate highway, major category	Interstate highways
A11	Primary limited access or interstate highway, unseparated	Interstate highways
A12	Primary limited access or interstate highway, unseparated, in	Interstate highways
A15	Primary limited access or interstate highway, separated	Interstate highways
A16	Primary limited access or interstate highway, separated, in	Interstate highways
A17	Primary limited access or interstate highway, separated,	Interstate highways
A20	Primary US and State highways, major category	State highways
A21	Primary US and State highways, unseparated	State highways
A22	Primary US and State highways, unseparated, in tunnel	State highways
A25	Primary US and State highways, separated	State highways
A26	Primary US and State highways, separated, tunnel	State highways
A27	Primary US and State highways, separated, underpassing	State highways
A30	Secondary State and County highways, major category	Major road
A31	Secondary State and County highways, unseparated	Major road
A32	Secondary State and County highways, unseparated, in tunnel	Major road
A33	Secondary State and County highways, unseparated,	Major road
A34	Secondary State and County highways, unseparated, with rail	Major road
A35	Secondary State and County highways, separated	Major road
A36	Secondary State and County highways, separated, in tunnel	Major road
A37	Secondary State and County highways, separated, underpassing	Major road
A38	Secondary State and County highways, separated, with center	Major road

Respiratory Health Outcomes in Respondents with Diagnosed and Undiagnosed Asthma

CHIS collected information regarding respiratory health outcomes from respondents with and without a diagnosis of asthma. Current asthmatics were asked to report *how often have you had asthma symptoms such as coughing, wheezing, shortness of breath, chest tightness or phlegm (not at all, less than every month, every month, every week, or every day)* and whether or not they experienced the following asthma-related health outcomes in the 12 months prior to their CHIS interview date: ED or urgent care visits, use of daily medication, and missed day care/school or work days. Although respondents were also asked the number of doctor visits for any reason during this period, we omitted this variable as an asthma outcome from our analyses because the question was not specific to doctor visits for asthma. Also, teenagers (12-17 years of age) were not asked if they missed school due to asthma, so this outcome is only available for children ages 0-11 years.

In addition to asking about asthma outcomes among respondents with a lifetime asthma diagnosis, CHIS 2003 contained a series of questions on asthma-like symptoms, i.e. wheezing in respondents never diagnosed with asthma. They were asked about the number of wheezing attacks, the number of times they sought medical attention for the breathing problem, and whether they missed any days of work or school/day care due to these problems in the 12 months prior to interview. Teenagers were not asked about how many attacks of wheezing or whistling they experienced or if they missed any school days due to wheezing. In summary, we examined the following health effect measures reported by respondents as occurring within the 12 months preceding the interview:

Health effect measures for CHIS 2003 respondents for CHIS 2003 child and adult respondents (except those noted below) with physician-diagnosed asthma:

The following measure is applied to those with **lifetime asthma diagnosis** only:

- Asthma episode or attack (dichotomous);

The following measures are applied to those with **current asthma** only:

- Asthma symptoms among those with current asthma: persistent asthma (with daily or weekly symptoms) vs. intermittent asthma (with monthly, less than monthly, or no symptoms);
- Currently taking daily medication to control asthma (dichotomous);
- ED/urgent care clinic visit for asthma, abbreviated to ED visits throughout the report (dichotomous);
- Two or more work days missed due to asthma, adults only (dichotomous); and
- Two or more days of day care or school missed due to asthma, children ages 0-11 only (dichotomous).

Health effect measures for CHIS 2003 child and adult respondents (except those noted below) ***with asthma-like symptoms*** *among those without asthma diagnoses:*

- Asthma-like symptoms, wheezing or whistling sound in chest (dichotomous);
- Two or more attacks of wheezing or whistling (dichotomous), excluding teen respondents;
- Sought medical care for such symptoms at least once (dichotomous);
- Two or more work days missed due to such symptoms, adults only (dichotomous); and
- Two or more days of day care or school missed due to such symptoms, children ages 0-11 only (dichotomous).

Potential Confounders and Vulnerability Characteristics

CHIS is a rich data source; in addition to health outcomes, information was collected on several important potential confounders and vulnerability characteristics for asthma or asthma-like symptoms. Particularly relevant to this study, CHIS 2003 collected information on basic demographics, overall health status, access to health care, asthma disease management, health behaviors, indoor asthma triggers, and housing conditions. For all the adjusted analyses, we included age, sex, race/ethnicity and federal poverty level (FPL) as covariates. We considered the following vulnerability-related risk factors as potential confounders of air pollution health effects estimates:

- **Access to health care**: having health insurance currently, having experienced delays in getting care for any medical reason, having a usual source of care;
- **Overall health status**: co-morbidity such as diabetes or heart disease;
- **Disease management/asthma severity indicators:** year of asthma diagnosis, receiving an asthma management plan, taking daily medication to control asthma;
- **Health behaviors:** being overweight/obese, smoking, and walking for transportation or leisure;
- **Housing conditions:** type of housing, such as single family dwelling or apartment, and crowding;
- **Indoor triggers**: smoking in the home, dog/cat in the home, cockroaches in the home, and
- **Residence**: urban/rural residence, length of residence at current address/neighborhood.

CHIS established if respondents' household income was above or below the FPL based on federal poverty guidelines. For example, 100% of the FPL means an annual household income of $8,980 for a one member household, $12,120 for a two member household, $15,260 for a three member household, and $18,400 for a four member household, while 200% of the FPL means household income was double the relevant amount. We decided to use 200% of the FPL as a cut point since the cost of living in California is higher in general than in most parts of the country due to housing costs.

CHIS used the U.S. Center for Disease Control body mass index (BMI) criteria to define overweight or obese based on self-reported height and weight. For instance, for adult men and women, the categories are underweight ≤18.5 BMI, normal weight=18.5–24.9 BMI, overweight=25–29.9 and obese=BMI of 30 or greater.

CHIS assigned respondents to four levels of urbanicity based on definitions developed by the commercial company Claritas: 1) urban, 2) 2^{nd} city, 3) suburban, 4) small town/rural. Using population density of an area and neighboring areas, Claritas classified mega-cities with density scores of 85-99 (on scale of 0 to 99) as "urban"; cities and big towns with density scores of 40-85 as "2^{nd} cities"; suburbs of urban and 2^{nd} city areas, with density scores of 40-90 as "suburban"; and exurbs and towns with density less than 40 as "town/rural". CHIS classified respondents based on the most prevalent Claritas household type in their residential zip code. Household crowding refers to households with more than one occupant per room (not counting bathrooms) based on the U.S. Census Bureau definition.

Statistical Methods

Once the data were linked, we conducted data analyses to answer the research questions whether the disproportionate burden of asthma or asthma-like symptoms among low SES individuals is associated with greater pollutant exposures, greater vulnerabilities or both (Objective 3-4). Under objective 3, we tested Hypothesis 1: Vulnerable sub-populations in California (e.g., racial/ethnic minorities and low-income individuals) have higher exposures to air pollution. We examined distributions of exposures for the four criteria air pollutants and traffic metrics among CHIS 2003 respondents and tested whether exposures varied by sub-populations, characterized by rural and urban residency (rural/town, urban, second city and suburban), age (0-5, 6-11, 12-17, 18-34, 35-64 and ≥65 years), gender, income level (0-199% FPL, 200-399% FPL, and ≥400% FPL), and by racial and ethnic group (white, Latino, African American, Alaskan Native/American Indian, Asian and Pacific Islanders and other minorities). We also examined differences in distributions of health outcomes across these subgroups. We performed t-tests and z-tests for proportions to identify disparities in pollutant exposures and respiratory outcomes within these sub-populations.

To examine whether there were positive associations between air pollution exposure and the respiratory outcomes of interest, and to identify additional factors that might contribute to the variations in association (Objectives 3 and 4), our analysis was comprised of several steps. First, we tested our hypothesis that individuals with asthma exposed to higher levels of air pollution are more likely to report adverse asthma outcomes, such as: asthma attacks or episodes, asthma emergency department (ED) visits, use of daily medication to control asthma, school or work absences, and daily/weekly asthma symptoms. Individuals with asthma-like symptoms and exposed to higher levels of air pollution are more likely to report: wheezing or whistling sound in the chest, attacks of wheezing or whistling (Hypothesis 2). We examined crude associations between individual air pollutants and asthma outcomes using tabular analyses and logistic regression modeling adjusting for age, sex, race/ethnicity and federal poverty level. For regression analyses, annual pollutant averages were included in the model as continuous measures scaled by a fixed number of units depending on the distributions of the pollutant averages and as commonly practiced in the literature. Specifically, we scaled O_3 by 10 ppb, NO_2 by 10 ppb, PM_{10} by 10 μg/m^3, and additionally we scaled $PM_{2.5}$ by 5 μg/m^3 based on the distribution after univariate analysis . Categorical variables were used for exceedance days and traffic measures to explore the shape of the exposure-outcome associations and evaluate possible exposure-response relations. To illustrate, we fit the following logistic model for the binary outcome asthma (noted here as A, where A=1 if a respondent reported persistent asthma (daily/weekly symptoms); a similar model would apply if we considered A to be an indicator of asthma-like symptom prevalence):

$$\text{logit}(\Pr(A=1 \mid O_3)) = \beta_0 + \beta_1 (O_3)$$

Here exp (β_1) represents the odds ratio for asthma corresponding to a 10 ppb change in O_3 exposure.

Second, to test if air pollution exposures, low SES status, and certain vulnerability factors associated with low SES exert independent adverse effects on individuals with asthma or asthma-like symptoms (Hypothesis 3), we used multiple logistic regression analyses to quantify associations between air pollution exposures and outcomes after including and excluding suspected confounders, such as insurance status, cigarette smoking, and delays in care. We fit three models for adults: (1) a base model, which includes each pollutant measure individually, plus age, race, federal poverty level, and sex; (2) the base model plus adjustment for major possible confounders related to access to care, health behaviors and overall health status, such as insurance status, overweight or obesity, heart disease, work status, and smoking status; and (3) the base model, including other possible confounders, such as urban vs. rural residence, having a usual source of care, having a delay in care for any medical reason, age of asthma onset, taking a daily asthma medication, having an asthma management plan, the presence of household smoking, having a dog or cat in the home, having cockroaches in the home, housing type, household crowding, having diabetes, and walking for leisure or transportation. For Model 3, we purposely excluded additional factors from Model 2, namely insurance status, overweight or obese, heart disease, work status, and smoking status, since some of them may be highly correlated with variables in Model 2, e.g. having heart disease and diabetes. Covariates that could be reasonably related were analyzed for possible correlations, and no significant correlations were observed for covariates in the same model. Covariates that could be reasonably related were analyzed for possible correlations, and no significant correlations were observed for covariates in the same model. We focused the Model 1-Model 3 analyses on three asthma-related outcomes: ED visits, daily asthma medication use, and 2 or more missed work days due to asthma in relationship to three criteria pollutants (O_3, PM_{10}, $PM_{2.5}$) for adults and use of daily asthma medication in relationship with $PM_{2.5}$ exposures for children. For children, the base model was the same as the base model for adults. In Model 2, we included the base model, plus adjusted for major possible confounders among children, such as insurance status, the presence of household smoking, having a dog or cat in the home, and having cockroaches in the home; Model 3 included the base model, as well as other possible confounders, such as urban vs. rural residence, having a delay in care for any medical reason, taking a daily asthma medication, having an asthma management plan, housing type, and household crowding.

Third, we tested the hypothesis that higher pollutant exposures interact with these vulnerability factors resulting in greater air pollution impacts on asthma in vulnerable sub-populations, i.e. racial/ethnic minorities, and low-income individuals (Hypothesis 4). We examined interactions between exposure and sub-populations characterized by age, race/ethnicity, income, and urban/rural residency. If an interaction term was statistically significant (based on a p-value ≤ 0.05), we calculated the interaction odds ratios using the formula:

$$OR(x)=\exp(b_1+b_x)$$

where 1 represents the reference group and x represents the comparison group. We then calculated the standard error (SE) using the formula:

$$SE(x)=\sqrt{(var_1+var_x+2cov_{1x})}$$

and used the standard error to calculate the confidence intervals (CI) for each interaction odds ratio, To calculate the CIs we used the formula:

$$95\%\ CI\ (x)=\exp[b_1+b_x\pm1.96*SE(x)]$$

If an interaction term was statistically significant (based on a p-value ≤ 0.05), we also conducted stratified analyses to examine effect measure modification in sub-populations, for example, by income level or racial/ethnic group. None of the stratified analyses produced meaningful results (at least one group's confidence intervals crossed the null) due to insufficient sample size (results not reported). As a result, we were unable to estimate population attributable risk (PAR) within the sub-group strata.

In addition to the above mentioned analyses, we also performed several sensitivity analyses. First, we stratified on length of residence in the same home or neighborhood (<3 years versus ≥3 years) to examine whether associations between air pollution exposure and odds of reporting asthma symptoms are greater in long-term residents who have been consistently exposed to higher pollution for a longer period of time. We also compared unemployed with employed adults to examine the influence of potentially greater measurement error in residential exposure measures for employed adults due to additional exposures incurred while commuting or at the workplace. Finally, we examined changes in air pollution effect estimates by residential distance to nearest monitoring station (3-, 5- and 10 miles), assuming exposure measures for subjects living closer to a station are less misclassified.

All analyses incorporated sampling weights that adjust for the unequal probabilities of selection into the CHIS sample. In our adjusted analyses, some study respondents were excluded due to missing data for exposure measures. Final sample sizes for each model are reported in the results tables. Additionally, weighted population estimates were calculated using a weight variable constructed through a complex, iterative process; the weight variable was then applied to the sample data. Separate weights were created for adults, children, and adolescents, which were then used to calculate statewide estimates representative of the entire state population. As a result, CHIS 2003 estimates were consistent with the 2003 California Department of Finance (DOF) Population Projections.

Air pollution, traffic and distance to roadway measures were checked for accuracy and completeness by inspecting the raw data files and univariate statistics for the measures. For many of the descriptive and regression analyses, SAS macros were developed with our statistical staff to expedite the analysis process and reduce the possibility for human error while cutting and pasting results into tables.

III. RESULTS

CHIS 2003 Respondents with Current Asthma

Exposure Distributions for CHIS 2003 Respondents with Current Asthma

Distributions of annual average pollutant exposures, exceedance days, and traffic density are shown in Table 6 in the Appendix. Among adults with current asthma, annual average exposures to O_3 ranged from 22.8 to 63.5 ppb, with a mean of 41.6 ppb, while NO_2 averages ranged from 1.6 to 36.1 ppb, with a mean of 21.1 ppb. Annual averages ranged from 12.3 µg/m^3 to 80.1 µg/m^3 for PM_{10} (mean=28.6 µg/m^3) and 4.1 µg/m^3 to 27.5 µg/m^3 for $PM_{2.5}$ (mean=16.0 µg/m^3).

Based on the 1-hr state standard, adults with current asthma had a maximum of 122 O_3 exceedance days and an average of 22.4 O_3 exceedance days in the year prior to CHIS interview; under the 8-hr state standard, there was a maximum of 153 exceedance days and a mean of 31.1 O_3 exceedance days. Using the 8-hr federal standard, there was a maximum of 114 exceedance days and an average of 16.8 exceedance days. Based on the PM_{10} federal standard, the maximum number of exceedance days was 4 days (mean=0.1 days); when using the state standard, the maximum was 66 exceedance days (mean=7.2 days). For $PM_{2.5}$, the maximum number of days exceeding the federal standard was 54 days, with an average of 15.5 exceedance days.

The mean traffic density within a 750-foot buffer was 66.0 VMT/day/meters^2, with a minimum of 0.09 and a maximum of 583.0.

Among children with current asthma, annual average O_3 exposure ranged from 23.0 ppb to 64.2 ppb with a mean of 41.3 ppb (Table 6 in Appendix). Annual PM_{10} averages ranged from 13.0-80.1 µg/m^3 (mean=30.0 µg/m^3), and $PM_{2.5}$ annual average exposure ranged from 7.4 to 26.2 µg/m^3 (mean=16.8 µg/m^3). NO_2 annual averages varied from 1.6-36.0 ppb, with a mean of 22.0 ppb.

The maximum number of O_3 exceedance days was 122 (mean=24.9 days) under the 1-hr state standard, 153 under the 8-hr state standard (mean=33.5 days), and 114 (mean=18.5 days) under the 8-hr federal standard. The maximum number of PM_{10} exceedance days was 4 (mean=0.1 days) under the federal standard and 65 (mean=7.8 days) under the state standard. The maximum number exceeding the federal $PM_{2.5}$ standard was 54, with an average 17.5 exceedance days. Traffic density ranged from 1.1-793.4 VMT/day/meters^2, with an average of 70.1 among children with current asthma (Table 6 in Appendix).

Frequencies for distance to roadway measures are shown in Table 7 in the Appendix. Less than 10% of adults with current asthma lived either within 300 meters of a state highway (5.4%) or interstate highway (9.9%). One-fifth (20.5%) of adults with current asthma lived within 50 meters of a major road. Five percent of children with current asthma lived within 300 meters of a state highway, and 12.1% lived within 300 meters of an interstate highway. One-fifth (19.1%) of children with current asthma lived within 50 meters of a major road.

Correlations among Air Pollution Exposure Estimates

We estimated Pearson correlation coefficients for exposure metrics assigned to CHIS 2003 respondents reported as current asthmatics (Table 8 in Appendix). Annual average exposure estimates for PM_{10} and $PM_{2.5}$ were strongly correlated (r=0.78), as were estimates for $PM_{2.5}$ and NO_2 (r=0.72). Moderate positive correlations were observed between PM_{10} and NO_2 (r=0.56), as well as PM_{10} and O_3 (r=0.49). Annual average exposures were strongly correlated with exceedance measures for O_3 (r≈0.8), while PM_{10} annual averages were strongly correlated with exceedances of the state (r=0.81) but not federal (r=0.43) standards. Annual average $PM_{2.5}$ exposures were moderately correlated with exceedances of the federal standard (r=0.69). There were low level correlations between annual average exposures and exceedance measures across pollutants. The traffic density and distance to roadway measures were weakly correlated with the criteria pollutant exposure metrics and with each other.

Health Outcomes and Characteristics of Adults and Children with Current Asthma

Table 9 below shows prevalence of asthma outcomes among respondents with current asthma. Among respondents with lifetime asthma, 35.0% of adults experienced an asthma attack in the year prior to their interview. Among adults with current asthma, the prevalence of daily or weekly symptoms was 29.8%. About half of adults with current asthma (47.6%) reported taking daily asthma medication, and 16.4% reported an ED visit within the past year. Additionally, 13.2% of adults with current asthma missed work at least twice.

Thirty-six percent of children with lifetime asthma experienced an asthma attack in the year prior to the interview. Of children with current asthma, 11.7% experienced daily or weekly symptoms, 21.7% had visited the ED, and 37.0% took daily asthma medication for their illness. Close to half of children with current asthma (45.9%) missed at least two school days.

Table 9. Prevalence of asthma outcomes for CHIS 2003 adults and children with current asthma[a]

	Adults (≥18 years)		Children (< 18 years)	
Outcome	n	% (Weighted)	n	% (Weighted)
Asthma Attack[b]	1,951	35.0	664	36.0
ED visits	500	16.4	237	21.7
Daily Asthma Medication	1,653	47.6	421	37.0
Missed At Least 2 Work/School Days Due to Asthma[c]	347	13.2	294	45.9
Daily/Weekly Asthma Symptoms	1,058	29.8	129	11.7

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only those who lived in the same home or neighborhood for at least 9 months were included.
[b]Respondents ever diagnosed with asthma who lived in the same home or neighborhood for at least 9 months were included.
[c]Data not collected for teen respondents.

Demographic characteristics of respondents with current asthma are shown in Table 10 in the Appendix. Among adults with current asthma, there were more women than men (65.3% vs. 34.7%). The majority of adult respondents with current asthma were between the ages of 35-64 (55.0%); 28.8% were 18-34, and 16.2% were 65 years old or older. The racial/ethnic distribution of the adult population with current asthma was as follows: 60.3% white, 17.3% Latino, 12.0% Asian/other, 8.4% African American, and 2.0% American Indian/Alaska Native.

Close to a third (34.3%) of adults with current asthma had received a high school diploma at most, while 43% had attended college or vocational school, and 11.3% had attended graduate school. The remaining 11.4% were under the age of 25, an age group that is often still pursuing an education, so educational attainment was not assessed for these respondents. Nearly two-fifths (38.2%) of respondents with current asthma were unemployed. Approximately one-third (32.5%) of adults with current asthma lived below 200% of the federal poverty level (FPL), 23.8% lived between 200-399% of the FPL, and the remaining 43.6% lived at or above 400% of the FPL.

While the majority of respondents were insured throughout the previous year, 16.1% of adults with current asthma were either not insured or only insured for part of the year. Similarly, more than 90% of adult respondents with current asthma reported a usual source of care; however, 21.0% reported a delay in needed care for any medical reason in the last 12 months. Only 22.1% of adults with current asthma reported visiting the doctor 0-1 time for any reason during the past year, while 45.4 % visited the doctor 2-5 times and 32.5% visited 6 or more times in the past year. The majority were diagnosed with asthma in adulthood. Nearly half (49.8%) of adults with current asthma were diagnosed between the ages of 18-64, and 5.4% were diagnosed at the age of 65 or older. Approximately a third (33.9%) were diagnosed between the ages of 0 and 11, and 10.9% were diagnosed between the ages of 12-17. Just less than half of adults with current asthma (47.6%) reported taking asthma medication daily, and only 37.6% said they had an asthma management plan.

When asked about current health status, 32.8% of adult respondents with current asthma stated their health status to be either poor or fair. The remaining 67.2% self-reported their health as good, very good, or excellent. Heart disease was reported in 11.3% of adults with current asthma; among them, 31.7% reported congestive heart failure. Based on BMI, 61.7% of adults with current asthma were classified as overweight or obese, as opposed to normal or underweight; 9.5% reported being diabetic, and 1.0% reported being borderline diabetic. While 45.5% of adults stated they currently or previously smoked, only 11.1% said they lived in a household with a current smoker. Nearly three-fourths (71.1%) of respondents reported walking for transportation or leisure. Almost half (47.7%) had dogs or cats in the home, and cockroaches were reported in the home among 12.2% of adults with current asthma.

The residences of most adults with current asthma were classified as urban (39.9%), as compared to 2nd city (27.5%), suburban (19.8%), or town/rural (12.7%). Most adult respondents (79.9%) had lived at their current addresses for 3 or more years. Two-thirds of adults (66.7%) stated they lived in houses, while the remainder described their housing units as apartments, duplexes, or mobile homes, and 16.3% of adults reported household crowding.

Child respondents with current asthma were 58.4% boys and 41.6% girls (Table 10 in Appendix). One-fifth (21.1%) of the children with current asthma were between the ages of 0-5, 37.5% were ages 6-11, and 41.4% were ages 12-17. Children with current asthma were 43.5% white, 26.9% Latino, 12.1% Asian/other, 14.6% African American, and 2.9% American Indian/Alaska Native. Over a third (38.3%) of children with current asthma had parents or guardians who had completed a high school education or less. Half of the parents or guardians of child respondents had completed college or vocational school, and the remaining 11.7% had graduate degrees. More than a third (38.3%) children with current asthma lived in households earning below 200% of the FPL, 30.8% lived between 200-399% of the FPL, and 30.8% lived in households earning 400% or more than the FPL.

The majority of children with current asthma were insured in the year prior to interview, though 4.9% of children were either not insured at all or only insured for part of the year. Most children (90.5%) were reported to have a usual source of care; still, 8.1% of children reportedly had a delay in needed care for any medical reason in the last 12 months. Among children with current asthma, 22.9% visited the doctor 0-1 time for any reason, 60.8% visited 2-5 times, and 16.3% visited 6 or more times in the past year. Most children with current asthma (90.5%) were diagnosed between the ages of 0 and 11. Thirty-seven percent took daily asthma medication, and 40.7% had an asthma management plan.

Most child respondents with current asthma were reported to have good, very good, or excellent health (81.3%), though 18.7% were reported to have poor or fair health. Based on BMI, 36.5% of teens with current asthma were classified as overweight or obese. Only 7.6% of children with current asthma lived in a household with a smoker. Two-fifths (40.9%) had dogs or cats in the home, while 15.4% had cockroaches in the home.

The greatest percentage of children with current asthma lived in urban residences (40.7%) compared to 2nd city (28.0%), suburban (21.0%), or town/rural residences (10.3%). More than three-fourths (76.6%) had lived at their current addresses for 3 or more years. Most children lived in houses (71.0%), while the remainder lived in apartments, duplexes, or mobile homes. One-third of children (33.4%) lived with household crowding.

Disparities in Asthma Outcomes and Exposure Measures among Sub-Populations

In this part of the study, we tested Hypothesis 1: Vulnerable sub-populations in California (e.g., racial/ethnic minorities and low-income individuals) have higher exposures to air pollution. We presented differences in estimated criteria pollutant exposures across various sub-populations, characterized by income level, racial and ethnic group, rural and urban residency, sex, and age. We also presented results regarding differences in distributions of asthma outcomes across these subgroups.

Disparities in Annual Average Criteria Pollutant Exposure Measures

Adult respondents with current asthma and living below 200% of the FPL had higher annual average exposures to all criteria pollutants, except for ozone, than those living at 400% or above the FPL (Table 11 in Appendix). Specifically, adults living below 200% of the FPL had a mean annual average NO_2 level of 22.4 ppb compared to 20.1 ppb among those living at or above 400% of the FPL. Additionally, adults living below 200% of the FPL were had mean PM_{10} and $PM_{2.5}$ exposures of 29.9 μg/m^3 and 16.7 μg/m^3, respectively, compared to 27.8 μg/m^3 and 15.0 μg/m^3 for those living at 400% or greater than the FPL. Mean annual average exposures to O_3 did not vary across poverty levels, however.

Disparities in criteria pollutant exposures were also observed across races/ethnicities. Latino adults had greater mean exposures to NO_2, PM_{10} and $PM_{2.5}$ than whites (24.2 ppb vs. 19.6 ppb, 31.3 μg/m^3 vs. 27.6 μg/m^3 and 17.9 μg/m^3 vs. 15.1 μg/m^3, respectively). Asian and Pacific Islander adults had greater mean NO_2 exposures (22.6 ppb vs. 19.6 ppb), and adult African Americans also had greater mean annual average exposure to $PM_{2.5}$ (16.2 μg/m^3 vs. 15.1 μg/m^3. However, whites had greater mean exposure to O_3 than any of the aforementioned groups (whites: 42.5 ppb; Latinos: 41.1 ppb; Asian and Pacific Islanders: 40.4 ppb; African Americans: 39.3 ppb).

There were also disparities in estimated criteria pollutant exposures across respondents' location of residence. Adults with current asthma living in urban residences had the highest exposure to NO_2, with a mean annual average exposure more than twice that of adult respondents living in rural/town residences (24.4 ppb vs. 10.6 ppb). Adults in urban residences had a mean $PM_{2.5}$ exposure of 16.2 $\mu g/m^3$, versus a mean of 15.1 $\mu g/m^3$ for adult respondents living in second cities and 10.8 $\mu g/m^3$ for adult respondents in town/rural residences. However, for all respondents, living farther from urban areas increased their annual exposure to O_3. Adult respondents in urban residences had a mean annual average O_3 exposure of 38.9 ppb compared to 42.8 ppb for those in second city residences, 44.6 ppb for those in suburban residences, and 47.6 ppb for those in town/rural residences.

Few significant differences were observed in annual pollutant exposure levels across age groups or for men versus women. Adult females had greater mean PM_{10} exposures at 29.1 $\mu g/m^3$ compared to 27.7 $\mu g/m^3$ among males, while adults ages 18-34 had greater mean NO_2 exposures than adults 65+ years of age (22.0 ppb vs. 19.9 ppb).

Among children with current asthma, those living between 0-199% of the FPL had a mean annual NO_2 exposure of 24.1 ppb versus 20.2 ppb for those living at or above 400% of the FPL (Table 11 in Appendix). For those living below 200% of the FPL and those living between 200-399% of the FPL, mean annual exposure to PM_{10} was estimated at 30.6 $\mu g/m^3$ and 31.3 $\mu g/m^3$ respectively, compared to 28.0 $\mu g/m^3$ for those living at or above 400% of the FPL. Mean $PM_{2.5}$ exposure was 17.5 $\mu g/m^3$ for children living at 0-199% of the FPL and 16.9 $\mu g/m^3$ for children living at 200-399% of the FPL, while children living at or above 400% of the FPL had a mean annual average exposure of 15.3 $\mu g/m^3$.

Children in minority populations were found to have higher average exposure to most air pollutants compared to their white peers. Latino, African American, and Asian/Pacific Islander/other children had higher mean annual exposures to NO_2 at 23.9 ppb, 22.1 ppb, and 23.8 ppb respectively, compared to 19.7 ppb for white children. Latino children had 17.2 $\mu g/m^3$ of annual average $PM_{2.5}$ exposure, and African American children had 17.8 $\mu g/m^3$ of annual average $PM_{2.5}$ exposure, compared to 15.7 $\mu g/m^3$ among white children. However, children of these race/ethnicities had lower O_3 exposures compared to white children (Latino: 40.6 ppb; African American: 40.0 ppb; Asian/PI/Other: 38.1 ppb; White: 43.1 ppb).

The mean annual NO_2 exposure for urban children was greater than mean exposures for children living in all other areas; for example, urban children had mean NO_2 averages nearly twice as high as children in town or rural residences (25.1 ppb vs. 13.7 ppb). Those living in non-urban areas had higher average exposure to O_3 than their urban-dwelling counterparts (2^nd^ city: 44.3 ppb; Suburban: 45.5 ppb; Town/Rural: 43.5 ppb vs. Urban: 37.8 ppb). Compared to urban children, suburban children had higher PM_{10} exposure (29.3 $\mu g/m^3$ vs. 33.7 $\mu g/m^3$), while town/rural children had lower $PM_{2.5}$ exposure than urban children (13.9 $\mu g/m^3$ vs. 17.0 $\mu g/m^3$). Among children with current asthma, boys had greater average exposure to $PM_{2.5}$ at 17.4 $\mu g/m^3$ versus 15.9 $\mu g/m^3$ for girls.

Table 11 (Highlights). Disparities in weighted mean annual pollutant concentrations by various demographic characteristics in CHIS 2003 children and adults with current asthma using bivariate analysis[a]

		NO_2 annual average (ppb)		O_3 annual average (ppb)		PM_{10} annual average ($\mu g/m^3$)		$PM_{2.5}$ annual average ($\mu g/m^3$)	
		Adult	Child	Adult	Child	Adult	Child	Adult	Child
Demographics		mean	mean	mean	mean	mean	mean	mean	mean
Household Federal Poverty Level	0 - 199 % FPL	22.4***	24.1***	41.1	41.0	29.9**	30.6*	16.7***	17.5**
	200 - 399 % FPL	20.7	20.6	42.1	42.0	28.1	31.3**	16.4**	16.9*
	≥ 400%†	20.1	20.2	41.8	41.1	27.8	28.0	15.0	15.3
Race/ethnicity	Latino	24.2***	23.9***	41.1*	40.6*	31.3***	30.8	17.9***	17.2*
	Alaskan Native / American Indian	19.2	23.9	42.0	47.0	29.4	32.1	15.3	19.3
	Asian / Pacific Islander / Other	22.6***	23.8**	40.4*	38.1***	28.8	28.8	16.2	16.6
	African American	21.0	22.1*	39.3***	40.0*	29.3	31.7	16.2*	17.8*
	White†	19.6	19.7	42.5	43.1	27.6	29.1	15.1	15.7

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
†Reference Group
*p < 0.05, **p < 0.01, ***p < 0.001

Disparities in Traffic Exposure Measures

Disparities in traffic density and residential proximity to roadways are shown in Table 12 in the Appendix. African American adults with current asthma had higher mean traffic density within a 750-foot buffer than white adults with current asthma (76.5 VMT/day/meters^2 vs. 60.2 VMT/day/meters^2). Urban dwelling adults had the highest mean traffic density at 80.6 VMT/day/meters ^{2}, compared to 59.4 VMT/day/meters^2 among second city dwellers, 59.5 VMT/day/meters ^{2} among suburban dwellers, and 40.6 VMT/day/meters ^{2} among town/rural dwellers.

Adults with current asthma with lower household incomes were more likely to live within 50 meters of a major road than those with higher incomes. Of those living below 200% of the FPL, 26.4% lived near a major road, compared to 23.7% among those living between 200-399% of the FPL, and 17.5% among those living at or above 400% of the FPL. Fewer Alaskan Natives/American Indians lived near an interstate highway compared to whites (3.4% vs. 9.8%). Urban adults with current asthma were more likely to live within 300 meters of an interstate highway than town/rural-dwelling asthmatic adults (10.9% vs. 6.9%); however, those living in towns or rural areas were more than three times as likely to live within 300 meters of a state highway as those living in urban areas (13.3% vs. 4.4%). Twice as many women lived within 300 meters of a state highway as men (6.5% vs. 3.3%).

Asthmatic children living closer to the federal poverty line were more likely to live near all types of roadways and in places with greater traffic density than children living farther from the poverty line. Children living between 0-199% of the FPL had a mean traffic density of 84.6 VMT/day/meters ^{2}, and children living between 200-399% of the FPL had a mean traffic density of 70.2 VMT/day/meters ^{2}, while children living at or above 400% of the FPL had a mean traffic density of only 52.7 VMT/day/meters^2 (Table 12 in Appendix). Both Latino and African American children had higher mean traffic density measures than white children (93.6 VMT/day/meters^2

and 89.8 VMT/day/meters^2 vs. 53.2 VMT/day/meters^2). Urban children had greater mean traffic density than both 2nd city and town/rural children (84.7 VMT/day/meters^2 vs. 57.4 VMT/day/meters^2 and 46.4 VMT/day/meters^2).

Children with asthma living at 0-199% of the FPL were close to three times more likely to live within 300 meters of a state highway compared to children from households earning 400% or more than the FPL (9.5% vs. 2.6%). Children living below 200% of the FPL were also more than twice as likely to live within 300 meters of an interstate highway (16.4% vs. 6.3%), and nearly a quarter (24.7%) lived within 50 meters of a major road compared to only 15.3% of children living at or above 400% of the FPL. Latino children were more than twice as likely as white children to live within 300 meters of an interstate highway (18.1% vs. 8.5%). Urban children were nearly twice as likely to live within 50 meters of a major road as 2nd city and town/rural dwelling children (27.1% vs. 14.2% and 15.6%).

Disparities in Asthma Outcomes

Table 13 in the Appendix provides prevalence measures for asthma outcomes among CHIS 2003 respondents with current asthma by various demographic characteristics. Adults living below 200% of the FPL had the highest prevalence for all measured asthma outcomes compared to those living at or above 400% of the FPL. The prevalence of asthma attacks for adults with lifetime asthma living below 200% of the FPL was 40.3% compared to 32.9% for those living at or above 400% of the FPL. The prevalence of asthma-related ED visits in the year prior to the CHIS 2003 interview for adults with current asthma living below 200% of the FPL was nearly twice that of adults with current asthma living at or above 400% of the FPL (24.6% vs. 12.6%). Over half (53.8%) of the adults with current asthma living below 200% of FPL used daily asthma medication as compared to 43.7% living at or above 400% of the FPL. The prevalence of daily/weekly asthma symptoms for adults with current asthma among adults living below 200% of the FPL and adults living at 200-399% of the FPL were greater than the prevalence among those living at or above 400% of the FPL (35.0% and 31.0% vs. 25.2%).

When comparing asthma outcomes in adults with current asthma by race/ethnicity, the percentage of Latino adults who visited the ED was over twice that of white adults (26.8% vs. 12.7%). African American adults reported a higher prevalence of daily asthma medication use at 59.4%, as compared to 48.0% of white adults. African Americans (19.7%), Latinos (21.9%), and Asian/Pacific Islander/others (16.7%) all reported missing at least 2 days of work at a prevalence higher than that of white respondents (8.8%). However, more white respondents (32.7%) reported daily/weekly asthma symptoms than either Latino (22.2%) or Asian/Pacific Islander/other respondents (25.2%).

The prevalence of asthma outcomes among those with current asthma differed by location of residence. Fewer adult respondents who lived in 2nd city residences (11.3%) or town/rural residences (9.6%) reported missing at least 2 days of work versus adults living in urban residences (15.6%). However, a lower percentage of adults living in urban residences reported daily/weekly asthma symptoms than adults living in town/rural residences (27.7% vs. 35.3%).

Among adults with lifetime asthma, more female respondents experienced an asthma attack than male respondents (41.8% vs. 25.9%). Furthermore, a higher percentage of women with current asthma had visited the ED (17.8% vs. 13.76%) and missed at least 2 days of work

(14.7% vs. 10.3%), and 31.7% of women with current asthma experienced asthma symptoms daily or weekly compared to 26.1% of men.

Significant differences in prevalence of asthma outcomes were found among the youngest and oldest respondents. More than two-thirds of adults with current asthma in the oldest age group, age 65 or older, took asthma medication daily at 67.3% compared to 48.4% of adults ages 35-64 and 35.2% of adults ages 18-34. More than one-third (38.1%) of adults with current asthma who were 65 or older reported experiencing daily or weekly asthma symptoms compared to 32.3% of those ages 35-64 and only 20.3% of those ages 18-34. However, adults ages 35-64 were more likely than those 65 or older to have visited the ED in the year prior to the interview (18.7% vs. 13.1%).

Among children with lifetime asthma, those living at or above 400% of the FPL had the highest prevalence of asthma attacks at 40.4% compared to 32.1% for those living at less than 200% of the FPL; however, for all other asthma outcomes, children with current asthma living below 200% of the FPL had the highest prevalence (Table 13 in Appendix). Children with current asthma whose household incomes fell below 200% of the FPL or between 200-399% of the FPL had higher prevalence of ED visits at 26.4% and 23.0% respectively, compared to 14.7% prevalence for those living at or above 400% of the FPL . Additionally, 45.7% of children with current asthma living below 200% of the FPL took asthma medication daily as opposed to only 28.7% living at or above 400% of the FPL. Over half (54.3%) of those living below 200% of the FPL were reported to have missed ≥2 days of school versus 33.2% of those living at or above 400% of the FPL.

The prevalence of asthma outcomes also varied by race/ethnicity among child respondents. Although Latino children with lifetime asthma had a lower prevalence of asthma attacks (29.8%) compared to white children (37.9%), more Latino children with current asthma took a daily asthma medication (45.4% vs. 31.5%). Nearly a third (32.3%) of African American children with current asthma reported visiting the ED in the past year compared to only 18.8% of white children with current asthma. Compared to children with current asthma living in town/rural residences, more children with current asthma living in urban residences had visited the ED (25.0% vs. 9.7%), taken daily asthma medication (39.6 % vs. 27.7%), and/or missed at least 2 days of school (45.1% vs. 29.2%).

The prevalence of an asthma attack in the past year was greater among children with lifetime asthma ages 0-5 (55.2%) and 6-11 years old (41.1%) than among children with lifetime asthma ages 12-17 (23.4%). While only 5.8% of children with current asthma in the oldest age group had visited the ED in the past 12 months, 26.7% of children with current asthma ages 6-11 and 44.3% of children with current asthma ages 0-5 had been taken to the ED within the year prior to the interview; yet, the oldest children with current asthma reported the highest prevalence of daily or weekly asthma symptoms at 16.1% in comparison to 8.9% among those 6-11 years old and 7.9% among those ages 0-5.

Associations between Air Pollution Exposure Metrics and Asthma Health Outcomes

In this part of the study, we tested Hypothesis 2, that individuals with asthma exposed to higher levels of air pollution are more likely to report adverse asthma outcomes, such as: asthma attacks or episodes, asthma emergency department (ED) visits, use of daily medication to control asthma, school or work absences, and daily/weekly asthma symptoms. We presented results of crude associations (Crude Odds Ratio) between individual air pollutants and asthma outcomes using tabular analyses and logistic regression modeling adjusting for age, sex, race/ethnicity and federal poverty level (Adjusted Odds Ratio).

Associations of 12-month pollutant averages with asthma outcomes

We observed positive associations between annual average criteria pollutant concentrations and asthma outcomes after controlling for age, race, poverty level and sex (Table 14). A 10 ppb increase in annual average O_3 concentration was associated with 20% higher odds of experiencing an asthma attack in the previous year (95% CI=1.05-1.36) among adults with lifetime asthma. A 10 ppb increase in annual average O_3 was also associated with a 22% (95% CI=1.04-1.43) increase in the odds of using daily asthma medication and a suggested 19% (95% CI=0.96-1.47) increase in the odds of visiting the ED within the past year in adults with current asthma.

Among adult current asthmatics, a 10 $\mu g/m^3$ increase in annual average PM_{10} concentration was associated with a 20% (95% CI 1.00-1.43) increase in the odds of visiting the ED within the past year and a 28% (95% CI=1.00-1.65) increase in the odds of 2 or more asthma-related absences from work. Associations were also suggested between PM_{10} and an increase in the odds of taking a daily asthma medication (OR=1.12, 95% CI=0.96-1.30). For every 5 $\mu g/m^3$ increase in annual average $PM_{2.5}$ concentration, the odds of taking daily asthma medication increased by 26% (95% CI=1.05-1.52); the odds of visiting the ED increased by 22% (95% CI=0.96-1.56); and the odds of experiencing daily/weekly asthma symptoms increased by 15% (95% CI=0.96-1.39). A 5 $\mu g/m^3$ increase in $PM_{2.5}$ concentration was also associated with a suggested 23% (95% CI=0.94-1.60) increase in the odds of missing ≥2 work days. Additionally, we observed a suggested 24% (95% CI=0.93-1.65) increase in odds of having ≥2 asthma-related work absences and an 18% (OR=1.18, 95% CI=0.92-1.50) increase in odds of visiting the ED per 10 ppb increase in mean annual average NO_2.

In general, we observed few associations between annual average concentrations of criteria pollutants and asthma symptoms in children. We estimated a 36% (95% CI=0.99-1.87) increase in the odds of taking a daily asthma medication and a 35% (95% CI=0.94-1.96) increase in missing 2 or more days of school per 10 ppb increase in annual average NO_2.

Table 14 (Highlights). Associations (OR (95% CI)) for 12-month pollutant averages and respiratory outcomes in CHIS 2003 adults and children with current asthma[a]

Pollutant	Asthma Attack[b]				ED Visit for Asthma				Daily Asthma Medication			
	Cases	Non-Cases	Adj. OR[d]	95% C.I.	Cases	Non-Cases	Adj. OR[d]	95% C.I.	Cases	Non-Cases	Adj. OR[d]	95% C.I.
Adults												
O_3 (per 10 ppb)	965	1582	**1.20**	[1.05, 1.36]	245	1372	1.19	[0.96, 1.47]	815	802	**1.22**	[1.04, 1.43]
PM_{10} (per 10 μg/m^3)	770	1272	1.04	[0.92, 1.18]	212	1092	**1.20**	[1.00, 1.43]	659	645	1.12	[0.96, 1.30]
$PM_{2.5}$ (per 5 μg/m^3)	592	974	1.07	[0.93, 1.24]	160	830	1.22	[0.96, 1.56]	494	496	**1.26**	[1.05, 1.52]
NO_2 (per 10 ppb)	782	1313	0.99	[0.84, 1.15]	200	1115	1.18	[0.92, 1.50]	667	648	1.08	[0.90, 1.30]
Children												
NO_2 (per 10 ppb)	282	430	0.97	[0.74, 1.27]	113	356	1.17	[0.81, 1.69]	171	298	1.36	[0.99, 1.87]

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same neighborhood for at least 9 months were included.
[b]Respondents ever diagnosed with asthma who lived within 5 miles of an air monitoring station and in the same home or neighborhood for at least 9 months were included.
[c]Adjusted for age, race, poverty level, and sex.
[d]Data not collected for teen respondents.

Table 14 (HIghlights). Associations (OR (95% CI)) for 12-month pollutant averages and respiratory outcomes in CHIS 2003 adults and children with current asthma[a] (continued)

Pollutant	Missed ≥2 School/Work Days Due				Daily/Weekly Asthma Symptoms			
	Cases	Non-Cases	Adj. OR[d]	95% C.I.	Cases	Non-Cases	Adj. OR[d]	95% C.I.
Adults								
O_3 (per 10 ppb)	176	1208	1.15	[0.91, 1.46]	504	1113	1.03	[0.87, 1.22]
PM_{10} (per 10 μg/m^3)	142	977	**1.28**	[1.00, 1.65]	415	889	1.03	[0.89, 1.20]
$PM_{2.5}$ (per 5 μg/m^3)	118	743	1.23	[0.94, 1.60]	316	674	1.15	[0.96, 1.39]
NO_2 (per 10 ppb)	147	985	1.24	[0.93, 1.65]	410	905	1.03	[0.85, 1.25]
Children								
NO_2 (per 10 ppb)	132	166	1.35	[0.94, 1.96]	51	418	1.13	[0.72, 1.75]

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same neighborhood for at least 9 months were included.
[b]Respondents ever diagnosed with asthma who lived within 5 miles of an air monitoring station and in the same home or neighborhood for at least 9 months were included.
[c]Adjusted for age, race, poverty level, and sex.
[d]Data not collected for teen respondents.

Associations for annual days exceeding air pollution standards and asthma outcomes

We observed associations between the number of days annually in which criteria pollutant levels exceeded maximum state and/or federal standards and asthma outcomes. Exceedances of state maximum 1-hr O_3 standards (i.e. over 36.7 days per year) were associated with a 40% (95% CI=1.03-1.91) increase in the odds of having an asthma attack in the past year among adults with lifetime asthma compared to those with <0.8 exceedance days (Table 15 in Appendix). They are also associated with a 91% (95% CI=1.14-3.18) increase in the odds of visiting the ED in the last 12 months and a 52% (95% CI=1.03-2.24) increase in the odds of taking a daily asthma medication in adults with current asthma. When looking at exceedance days for the O_3 1-hr state standard, there appeared to be a pollutant exposure-response trend for all three outcomes mentioned above.

Based on the O_3 8-hr state standard, adults with lifetime asthma and ≥51.2 exceedance days were 44% more likely to have asthma attacks in the previous year (95% CI=1.07-1.94). Adults with current asthma and ≥51.2 exceedance days were 50% more likely to require a daily asthma medication (95% CI=1.04-2.18) than those with <1.9 exceedance days.

In addition to associations with O_3, asthma outcomes were also associated with exceedance days for particulate matter. Adults with current asthma and ≥6.6 days when PM_{10} concentrations exceeded the 24-hr state standard had 77% (95% CI=1.05-2.97) greater odds of visiting the ED in the year prior to the interview. Adults with current asthma and ≥23.9 days when $PM_{2.5}$ concentrations exceeded the 24-hr federal standard were twice (OR=2.01, 95% CI=1.10-3.68) as likely to visit the ED in the past year than adults with <4.8 exceedance days, and there was a suggested exposure-response trend for this outcome. Adult asthmatics with ≥23.9 exceedance days were also 66% (95% CI=1.02-2.68) more likely to experience daily or weekly asthma symptoms compared to those with <4.8 $PM_{2.5}$ exceedance days.

Among current asthmatics, children with ≥36.7 days when maximum 1-hr O_3 concentrations exceeded the 1-hr state standard were 3 times as likely (OR=3.00, 95% CI=1.20-7.51) to miss 2 or more school days compared to children with <0.8 exceedance days (Table 15 in Appendix). We did not observe associations between any of the other exceedance measures or asthma outcomes in children.

Further associations were suggested between particulate matter exceedance days and asthma outcomes among adults with current asthma. A suggested 70% (95% CI=0.91-3.18) increase in the odds of missing ≥2 work days due to asthma was observed for respondents with ≥6.6 PM_{10} exceedance days compared to their counterparts with <1.6 exceedance days. Also, a suggested 49% (95% CI=0.92-2.39) increase in the odds of needing a daily asthma medication was observed for those with ≥23.9 compared to those with <4.8 $PM_{2.5}$ exceedance days.

Associations for traffic density/distance to roadway and asthma outcomes

We observed few consistent associations between traffic density and residential proximity to roadway measures and asthma outcomes (Table 16 in Appendix). An interquartile increase in traffic density within 750 feet of respondent's homes was associated with a 8% (95% CI= 0.97-1.21) increase in odds of reporting asthma ED visits in the past year, but analyses based on quartiles of exposure did not demonstrate a clear exposure-response pattern for this outcome. Traffic density was not associated with any other outcome in adults. Living within 300 m of an interstate highway was associated with a 51% (95% CI=0.91-2.48) suggested increase in the odds of visiting the ED in the past year, as well as a 34% (95% CI=0.95-1.90) suggested increase in the odds of needing a daily asthma medication.

For children with current asthma, we observed a 58% (95% CI=0.94-2.66) suggested increase in the odds of taking an asthma medication daily for children in the 3^{rd} versus 1^{st} quartile of TD exposure, but a 43% (95% CI=0.83-2.47) for children in the highest TD quartile (Table 16 in Appendix).

Pollutant and Asthma Outcome Relationship after Adjusting Vulnerability (Confounding) Factors

In this part of the study, we tested hypothesis if air pollution exposures, low SES status, and certain vulnerability factors associated with low SES exert independent adverse effects on individuals with asthma (Hypothesis 3). We fit three models (1) a base model, which includes each pollutant measure, plus socio-demographics, such as age, race, federal poverty level, and sex; (2) the base model plus adjustment for access to care (i.e. health insurance) and major risk factors, such as smoking and being overweight or obese, and heart disease; and (3) the base model plus adjustment for indicators of asthma severity, such as age of asthma onset, taking a daily asthma medication, having an asthma management plan; as well as indoor triggers, such as the presence of household smoking, having a dog or cat in the home, having cockroaches in the home, housing type, and household crowding.

Associations between ED visits and O_3 adjusting for vulnerability factors in adults

We observed persistent associations between ED visits and O_3, controlling for vulnerability factors by using three different models in order to observe variations in the pollutant effect when these factors are taken into account (Table 17). Specifically, for O_3, a positive association between increases in O_3 and ED visits remained across all models. We observed a suggested 19% (95% CI=0.96-1.47) increase in the odds of an ED visit in the last year per 10 ppb increase in annual average O_3 concentration among adults with current asthma, when using our base model after adjusting for socio-demographics (Model 1). The estimated association between annual average O_3 and ED visits remained after further adjusting for access to care and risk behaviors under Model 2 (OR= 1.18; 95% CI=0.95-1.47) and after adjusting for asthma severity and indoor triggers in Model 3 (OR=1.15, 95% CI=0.91-1.45), though in Model 3, the estimated odds were slightly lower and less precise.

Furthermore, we observed variations in the increased odds of ED visits across races/ethnicities, age groups, poverty levels, and genders, which persisted across all three models. Based on Model 1, African Americans were 86% (95% CI= 1.04-3.32) more likely and Latinos were twice as likely (95% CI=1.27-3.23) to have an ED visit as white respondents. Adults with current asthma ages 35-64 years old were nearly two times (OR=1.91, 95% CI=1.15-3.20) more likely to have visited the ED in the last year than asthmatic adults 65 years or older, and respondents living below 200% of the FPL had 93% greater odds of an ED visit (95% CI=1.26-2.97) compared to those living at or above 400% of the FPL. Women had higher odds of ED visits than men (OR=1.45, 95% CI=0.97-2.18). Under model 2, Latino and African American respondents, those 35-64 years old, females, and those living below 200% of the FPL continued to have higher odds of ED visits. Under Model 3, the pattern of increased odds of ED visits remained the same in general, though for African Americans and women the estimated odds of ED visits moved closer toward the null.

In addition to the above associations observed in all models, under Model 2 we observed a 69% (95% CI=1.01-2.84) increase in the odds of having an ED visit in the last year for those who reported having heart disease and a 65% (95% CI=1.08-2.54) increase in odds for those with adult onset of asthma compared to childhood onset. Although counterintuitive, under Model 3 those not using a daily asthma medication and those without an asthma management plan had lower odds of ED visits (OR=0.35, 95% CI=0.23-0.52 and OR=0.52, 95% CI=0.36-0.76, respectively).

Associations between ED visits and PM_{10} adjusting for vulnerability factors in adults

A positive association between ED visits and annual average PM_{10} concentration persisted across all models. We estimated a 20% (95% CI=1.00-1.43) increase in the odds of ED visits in the last 12 months per 10 $\mu g/m^3$ increase in annual average PM_{10} after adjusting for socio-demographics under our base model (Model 1). The association stayed nearly the same after further adjusting for access to care and risk behaviors under Model 2 (OR=1.18, 95% CI=0.95-1.47) and increased slightly (OR=1.25, 95% CI=1.03-1.51) after adjusting for asthma severity and indoor triggers under Model 3.

When controlling for PM_{10} exposure, positive associations between ED visits and race/ethnicity, age, and poverty level remained across all models. Based on Model 1, we estimated increased odds of ED visits for adults 35-64 years versus ≥65 years (OR=1.76, 95% CI=0.99-3.13), Latinos versus whites (OR=2.42, 95% CI=1.46-4.00), and individuals living below 200% of the FPL versus those at ≥400% of the FPL (OR=2.02, 95% CI=1.27-3.20). Under Models 2 and 3, the strength of association between ED visits and being Latino remained approximately the same. Compared to Model 1, the odds of ED visits increased for respondents ages 35-64, but decreased for those living below 200% of the FPL under Models 2 and 3.

We observed associations between ED visits and several model-specific vulnerability factors when also controlling for PM_{10}. Having heart disease doubled the odds of an ED visit (OR=2.07, 95% CI=1.22-3.52), and adult versus childhood asthma onset increased the odds of an ED visit by 50% (95% CI=0.94-2.39). Those not taking a daily asthma medication (OR=0.30, 95% CI=0.20-0.47) and those without an asthma management plan (OR=0.56, 95% CI=0.37-0.84) were less likely to visit the ED.

Associations between ED visits and $PM_{2.5}$ adjusting for vulnerability factors in adults

A 5 $\mu g/m^3$ increase in annual average $PM_{2.5}$ increased the odds of visiting the ED in the last 12 months by 22% (95% CI=0.96-1.56) among adults with current asthma after adjusting for socio-demographics per Model 1. The positive association between ED visits and $PM_{2.5}$ remained nearly the same after further adjusting for access to care and risk behaviors under Model 2 (OR=1.21, 95% CI=0.95-1.54) and after adjusting for asthma severity and indoor triggers under Model 3 (OR=1.20, 95% CI=0.92-1.56).

When controlling for $PM_{2.5}$, under Model 1 we observed that Latinos (OR=2.03, 95% CI=1.18-3.49) and African Americans (OR=1.92, 95% CI=0.99-3.71) were twice as likely to visit the ED. Adult asthmatics living below 200% of the FPL had odds 84% (95% CI=1.11-3.03) greater than those living at 400% of the FPL or above. The positive association between ED visits and being Latino persisted across all models, though increased under Model 2, while the positive association between ED visits and being African American was present in Model 2, but not Model 3. For respondents living below 200% of the FPL, estimated odds moved toward the null under Models 2 and 3.

Similar to associations seen when controlling for O_3 and PM_{10} in Models 2 and 3, heart disease increased the odds of ED visits by 2.12 times (95% CI=1.20-3.73) when controlling for $PM_{2.5}$. A protective relationship was observed between $PM_{2.5}$ and not taking a daily asthma medication (OR=0.29, 95% CI=0.17-0.49), as well as not having an asthma management plan (OR=0.63, 95% CI=0.40-1.00).

Associations between daily asthma medication and O_3 adjusting for vulnerability factors in adults

For every 10 ppb increase in annual average O_3 concentration, we estimated a 22% (95% CI=1.04-1.43) increase in the odds of needing a daily asthma medication among adults with current asthma, according to Model 1 after adjusting for socio-demographics (Table 18). The relationship between O_3 and daily asthma medication was similar across all models after further adjusting for access to care and risk behaviors or asthma severity and indoor triggers.

Based on Model 1, being 18-34 years old (OR=0.32, 95% CI=0.21-0.48) or 35-64 (OR=0.55, 95% CI=0.39-0.78) was found to have a protective effect against needing a daily asthma medication. In addition, we observed suggested associations between taking daily asthma medication and being African American (OR=1.49, 95% CI=0.92-2.41) and living below 200% of the FPL (OR=1.30, 95% CI=0.94-1.79). As in Model 1, being <65 versus ≥65 years of age was found to have a protective effect in general, and African Americans were more likely to need a daily asthma medication under Models 2 and 3. The positive association between daily asthma medication and living below 200% of the FPL did not appear under Model 2, but was seen in Model 3.

Model-specific vulnerability factors were also found to have associations with increased odds of needing a daily asthma medication. Having current insurance (OR=1.56, 95% CI=1.02-2.38), having heart disease (OR=1.77, 95% CI=1.16-2.69), and ever smoking (OR=1.41, 95% CI=1.07-1.86) were found to increase respondents' odds of daily asthma medication use under Model 2. Moreover, individuals without a usual source of care (OR=2.28, 95% CI=1.35-3.85) had higher odds of daily asthma medication use under Model 3, while not having an asthma management plan (OR=0.46, 95% CI=0.35-0.61) and having cockroaches in the home (OR=0.58, 95% CI=0.38-0.88) were shown to be protective against needing a daily asthma medication.

Associations between daily asthma medication and PM_{10} adjusting for vulnerability factors in adults

According to our base model (Model 1), a 10 $\mu g/m^3$ increase in annual average PM_{10} was associated with a 12% (95% CI=0.96-1.30) increase in the odds of daily asthma medication use after adjusting for socio-demographics among adults with current asthma. The positive association between PM_{10} and daily medication use stayed the same under Model 2 (OR=1.12, 95% CI=0.96-1.30) after further adjusting for access to care and risk behaviors and increased slightly after adjusting for asthma severity and indoor triggers under Model 3 (OR=1.23, 95% CI=1.04-1.45).

Under Model 1, African Americans (OR=1.85, 95% CI=1.07-3.19) and American Indian/Alaska Natives (OR=2.46, 95% CI=0.92-6.62) had higher odds of daily asthma medication use. Younger adult respondents were less likely to need a daily asthma medication compared to adult respondents ≥65 years (18-34 years: OR=0.32, 95% CI=0.20-0.51; 35-64 years: OR=0.53, 95% CI=0.36-0.79).

When controlling for PM_{10} exposure, the positive association between odds of daily asthma medication use and being African American increased in Models 2 and 3, while estimates for American Indian/Alaska Natives remained the same and precision increased. The protective effect of being between the ages of 18-34 years old remained, but the protective effect for those 35-64 years old was only evidenced under Model 2.

Similar to Models 1-3 when controlling for O_3, adults with heart disease had 81% (95% CI=1.12-2.91) higher odds, and those who had ever smoked had 31% (95% CI=0.97-1.77) higher odds of needing a daily asthma medication under Model 2. Under Model 3, odds of daily medication use was greater for those with a usual source of care (OR=1.83, 95% CI=1.02-3.28). On the other hand, those without an asthma management plan (OR=0.44, 95% CI=0.32-0.60), those who had experienced a delay in care for any medical reason (OR=0.68, 95% CI=0.47-0.97), and those with the presence of cockroaches in the home (OR=0.54, 95% CI=0.33-0.87) were less likely to use a daily asthma medication.

Associations between daily asthma medication and $PM_{2.5}$ adjusting for vulnerability factors in adults

The odds of daily medication use increased 26% (95% CI=1.05-1.52) per 5 $\mu g/m^3$ increase in annual average $PM_{2.5}$ concentration level after adjusting for socio-demographics based on Model 1. The odds of using a daily asthma medication increased after further adjusting for access to care and risk behaviors under Model 2 (OR=1.30, 1.07-1.57), and increased even further after adjusting for asthma severity and indoor triggers under Model 3 (OR=1.44, 95% CI=1.18-1.76).

Under Model 1, respondents with current asthma between the ages of 18-34 and 35-64 years were less likely to need daily asthma medication than respondents 65 years old or older (OR=0.40, 95% CI=0.24-0.66 and OR=0.56, 95% CI=0.36-0.88, respectively). There also appeared to be a positive association between daily asthma medication use and being African American (OR=1.62, 95% CI=0.92-2.84). Under Models 2 and 3, younger respondents, ages 18-34, were still less likely to use a daily asthma medication than current asthmatics 65 years old or older, but the previous negative associations for ages 35-64 years (OR=0.64, 95% CI=0.42-0.97) only remained under Model 3. Positive associations between increased odds of taking a daily asthma medication and being African American persisted under Models 2 and 3.

In addition to the above associations seen across all models when controlling for $PM_{2.5}$, being currently insured (OR=1.86, 95% CI=1.11-3.11), having heart disease (OR=1.73, 95% CI=1.05-2.84), and ever smoking (OR=1.47, 95% CI=1.04-2.06) all increased the odds of daily asthma medication use under Model 2. Based on Model 3, those with a usual source of care had increased odds (OR=3.07, 95% CI=1.57-5.99), while those without an asthma management plan (OR=0.41, 95% CI=0.29-0.59) and those with cockroaches in the home (OR=0.59, 95% CI=0.36-0.97) were protected against daily asthma medication use.

Associations between missed work days and O_3 adjusting for vulnerability factors in adults

According to results from Model 1, we observed a 15% suggested increase (95% CI=0.91-1.46) in the odds of missing ≥2 days of work as O_3 annual averages increased by 10 ppb among adults with current asthma after adjusting for socio-demographics (Table 19). Model 2 appeared to also evidence a 15% increase (95% CI=0.91-1.44) after further adjusting for access to care and risk behaviors, and Model 3 appeared to evidence a 13% increase in odds of missing ≥2 days of work due to asthma after adjusting for asthma severity and indoor triggers (95% CI=0.88-1.44), though precision was low.

Based on Model 1, African American, Asian/Pacific Islander/Other race, and Latino adults were two to four times more likely to miss ≥2 days of work than white adults (OR=3.79, 95% CI=2.02-7.13; OR=2.06, 95% CI=1.07-3.97; OR=3.42, 95% CI=2.06-5.68, respectively). Women were twice as likely to miss ≥2 days of work as men (OR=2.26, 95% CI=1.39-3.68). Living below 200% of the FPL was shown to be protective against missing 2 or more work days. For all O_3 vulnerability characteristic models and all subsequent pollutant vulnerability characteristic models, the odds ratios for the age variable were not estimated due to small sample size. Associations observed based on results from Model 1 were maintained in Models 2 and 3, and changes in point estimates for these factors were minimal. Beyond the associations evidenced across all models controlling for O_3, those without a daily asthma medication (OR=0.44, 95% CI=0.28-0.69) were less likely to miss ≥2 days of work.

Associations between missed work days and PM_{10}, adjusting for vulnerability factors in adults

Based on Model 1 when controlling for PM_{10}, we observed a 28% (95% CI=1.00-1.65) increase in the odds of missing ≥2 days of work per 10 $\mu g/m^3$ increase in annual average PM_{10} concentration after adjusting for socio-demographics. Associations between PM_{10} and missing ≥2 days of work were similar after further adjusting for access to care and risk behaviors in Model 2 (OR=1.30, 95% CI=1.01-1.68) or adjusting for asthma severity and indoor triggers in Model 3(OR=1.25, 95% CI=0.96-1.63).

Both African Americans and Latinos were nearly 4 times more likely to miss ≥2 days of work than their white counterparts (OR=3.60, 95% CI=1.73-7.47 and OR=3.60, 95% CI=2.00-6.47, respectively), and women were twice as likely as men to miss ≥2 days of work (OR=2.14, 95% CI=1.25-3.65) under Model 1. Positive associations were similarly maintained for African Americans, Latinos, and women under Models 2 and 3. As with all models controlling for O_3 mentioned above, those not taking a daily asthma medication were less likely to miss ≥2 days of work than those taking a daily asthma medication (OR=0.44, 95% CI=0.26-0.74).

Associations between missed work days and $PM_{2.5}$ adjusting for vulnerability factors in adults

We observed a 23% suggested increase in the odds of missing ≥2 days of work (95% CI=0.94-1.60) for every 5 $\mu g/m^3$ increase in $PM_{2.5}$ annual averages after adjusting for socio-demographics under Model 1. The association between missing ≥2 days of work and $PM_{2.5}$ was of similar magnitude after further adjusting for access to care and risk behaviors in Model 2 (OR=1.23, 95% CI=0.94-1.60) and after adjusting for asthma severity and indoor triggers in Model 3 (OR=1.24, 95% CI=0.93-1.66).

African American and Latino respondents were more likely to miss ≥2 days of work than white respondents (OR=4.69, 95% CI=2.24-9.81 and OR=3.28, 95% CI=1.76-6.10, respectively), as were women compared to men (OR=2.23, 95% CI=1.24-4.03) under Model 1. Respondents living below 200% of the FPL appeared to be less likely to miss ≥2 days of work than those living at or above 400% of the FPL (OR=0.37, 95% CI=0.21-0.67). Positive associations for African Americans, Latinos, and women and the negative association for those living below 200% of the FPL remained similar in Models 2 and 3. Similar to Models 1-3 controlling for O_3 and PM_{10}, those not taking a daily asthma medication were less likely to miss ≥2 days of work (OR=0.49, 95% CI=0.28-0.86).

Associations between daily asthma medication and $PM_{2.5}$ adjusting for vulnerability factors in children

Based on Model 1, we observed a 20% (95% CI=0.88-1.63) suggested increase in the odds of using a daily asthma medication for every 5 $\mu g/m^3$ increase in annual average $PM_{2.5}$ concentration after adjusting for socio-demographics among children with current asthma. The positive association between daily asthma medication use and $PM_{2.5}$ persisted across all models, though confidence intervals crossed the null after adjusting for insurance status, the presence of household smoking, having a dog or cat in the home, and having cockroaches in the home (Model 2); as well as after adjusting for urban vs. rural residence, having a delay in care, taking a daily asthma medication, having an asthma management plan, housing type, and household crowding in Model 3.

In Model 1, children living below 200% and those living between 200-399% of the FPL had three times greater odds of using a daily asthma medication compared to those living at ≥400% of the FPL (OR=2.64, 95% CI=1.22-5.72; OR=3.00, 95% CI=1.46-6.14). Associations between living below 200% or between 200-399% of the FPL and using a daily asthma medication were similar in Models 2 and 3. In addition to associations seen across models, children without an asthma management plan had lower odds of using a daily asthma medication (OR=0.38, 95% CI=0.19-0.75), according to results from Model 3.

Table 17 (Highlights). Associations between ED visits and pollutants (O_3, PM_{10}, and $PM_{2.5}$) adjusting for vulnerability characteristics among CHIS adults with current asthma[a]

		O_3 (per 10 ppb)									PM_{10} (per 10 μg/m^3)									$PM_{2.5}$ (per 5 μg/m^3)								
		Model 1 (245, 1372)[b]			Model 2[c] (245, 1365)[b]			Model 3[d] (240, 1337)[b]			Model 1 (212, 1092)[b]			Model 2[c] (212, 1085)[b]			Model 3[d] (209, 1058)[b]			Model 1 (160, 830)[b]			Model 2[c] (160, 825)[b]			Model 3[d] (157, 807)[b]		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average		1.19	0.96	1.47	1.18	0.95	1.47	1.15	0.91	1.45	1.20	1.00	1.43	1.18	0.99	1.42	1.25	1.03	1.51	1.22	0.96	1.56	1.21	0.95	1.54	1.20	0.92	1.56
Age (Ref. ≥65)																												
	18 - 34	1.09	0.61	1.93	1.49	0.78	2.85	2.05	1.00	4.20	1.00	0.53	1.88	1.44	0.72	2.90	1.91	0.88	4.16	0.94	0.45	1.93	1.66	0.76	3.63	1.31	0.57	2.99
	35 - 64	1.91	1.15	3.20	2.26	1.30	3.94	2.33	1.29	4.19	1.76	0.99	3.13	2.19	1.20	4.00	2.29	1.19	4.41	1.64	0.86	3.15	2.20	1.13	4.26	1.88	0.94	3.76
Race (Ref. White)																												
	African American	1.86	1.04	3.32	1.76	0.97	3.20	1.40	0.73	2.68	1.42	0.74	2.71	1.30	0.67	2.53	1.16	0.58	2.29	1.92	0.99	3.71	1.95	0.98	3.87	1.38	0.71	2.67
	AI/AN	1.51	0.43	5.29	1.46	0.42	5.16	0.96	0.29	3.16	1.36	0.38	4.93	1.27	0.33	4.88	0.83	0.24	2.91	0.97	0.16	5.95	0.89	0.14	5.58	0.59	0.10	3.34
	Asian / PI / Other	1.26	0.71	2.26	1.38	0.77	2.47	1.41	0.79	2.51	0.80	0.42	1.54	0.84	0.44	1.59	0.90	0.45	1.79	0.96	0.47	1.96	1.08	0.52	2.23	0.92	0.46	1.84
	Latino	2.03	1.27	3.23	2.08	1.30	3.35	2.23	1.32	3.78	2.42	1.46	4.00	2.46	1.47	4.12	2.40	1.37	4.22	2.03	1.18	3.49	2.38	1.35	4.22	2.05	1.09	3.88
Poverty (Ref. ≥400%)																												
	0 - 199% FPL	1.93	1.26	2.97	1.62	1.02	2.57	1.82	1.12	2.95	2.02	1.27	3.20	1.72	1.06	2.80	1.95	1.15	3.31	1.84	1.11	3.03	1.51	0.90	2.54	1.64	0.93	2.90
	200 - 399% FPL	1.14	0.69	1.89	1.07	0.64	1.80	1.11	0.68	1.83	1.34	0.79	2.27	1.31	0.76	2.25	1.37	0.79	2.39	1.09	0.57	2.06	1.09	0.58	2.05	0.98	0.51	1.90
Sex																												
	Female vs. Male	1.45	0.97	2.18	1.46	0.97	2.21	1.37	0.89	2.10	1.28	0.83	1.97	1.23	0.80	1.88	1.25	0.80	1.96	1.45	0.89	2.37	1.50	0.91	2.45	1.51	0.89	2.55
Heart Disease																												
	Yes vs No				1.69	1.01	2.84							2.07	1.22	3.52							2.12	1.20	3.73			
Onset of Asthma																												
	Adult vs Child							1.65	1.08	2.54							1.50	0.94	2.39									
Daily Asthma Medication																												
	No vs Yes							0.35	0.23	0.52							0.30	0.20	0.47							0.29	0.17	0.49
Asthma Management Plan																												
	No vs Yes							0.52	0.36	0.76							0.56	0.37	0.84							0.63	0.40	1.00

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.

[b](Cases, Non-cases)

[c]Model 2 controlled for the following vulnerability factors: insurance status, obesity, heart disease, smoking status, and work status.

[d]Model 3 controlled for the following vulnerability factors: urban/rural, usual source of care, delay in care, onset of asthma, daily asthma medication, asthma management plan, household smoking, dog or cat in home, cockroaches in home, housing type, household crowding, diabetes, and walking.

Table 18 (Highlights). Associations between daily asthma medication and pollutants (O_3, PM_{10}, and $PM_{2.5}$) adjusting for vulnerability characteristics among CHIS adults with current asthma[a]

		O_3 (per 10 ppb)									PM_{10} (per 10 μg/m^3)									$PM_{2.5}$ (per 5 μg/m^3)								
		Model 1 (815, 802)[b]			Model 2[c] (811, 799)[b]			Model 3[d] (789, 788)[b]			Model 1 (659, 645)[b]			Model 2[c] (654, 643)[b]			Model 3[d] (634, 633)[b]			Model 1 (494, 496)[b]			Model 2[c] (491, 494)[b]			Model 3[d] (479, 485)[b]		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average		1.22	1.04	1.43	1.23	1.05	1.46	1.24	1.05	1.48	1.12	0.96	1.30	1.12	0.96	1.30	1.23	1.04	1.45	1.26	1.05	1.52	1.30	1.07	1.57	1.44	1.18	1.76
Age (Ref. ≥65)																												
	18 - 34	0.32	0.21	0.48	0.52	0.33	0.83	0.30	0.19	0.48	0.32	0.20	0.51	0.51	0.30	0.87	0.33	0.19	0.55	0.40	0.24	0.66	0.80	0.44	1.44	0.41	0.23	0.73
	35 - 64	0.55	0.39	0.78	0.76	0.52	1.12	0.51	0.35	0.74	0.53	0.36	0.79	0.72	0.46	1.13	0.50	0.32	0.77	0.56	0.36	0.88	0.91	0.55	1.49	0.52	0.32	0.85
Race (Ref. White)																												
	African American	1.49	0.92	2.41	1.54	0.95	2.49	1.52	0.92	2.51	1.85	1.07	3.19	1.98	1.15	3.41	2.16	1.22	3.84	1.62	0.92	2.84	1.87	1.05	3.32	1.76	0.97	3.18
	AI/AN	1.88	0.74	4.75	1.89	0.77	4.66	1.77	0.74	4.24	2.46	0.92	6.62	2.56	0.97	6.77	2.47	1.02	5.99	1.85	0.55	6.29	1.85	0.57	6.00	1.84	0.59	5.73
	Asian / PI / Other	0.75	0.47	1.20	0.86	0.54	1.38	0.71	0.44	1.16	0.72	0.41	1.26	0.81	0.46	1.42	0.86	0.48	1.53	0.77	0.45	1.31	0.84	0.49	1.42	0.87	0.50	1.52
	Latino	0.81	0.54	1.20	0.90	0.59	1.36	0.90	0.58	1.39	1.06	0.66	1.68	1.17	0.72	1.90	1.33	0.80	2.21	0.65	0.40	1.06	0.79	0.48	1.29	0.78	0.45	1.36
Poverty (Ref. ≥400%)																												
	0 - 199% FPL	1.30	0.94	1.79	1.16	0.82	1.65	1.41	0.98	2.03	1.16	0.81	1.65	1.06	0.72	1.57	1.28	0.86	1.90	1.28	0.86	1.91	1.12	0.73	1.72	1.45	0.94	2.22
	200 - 399% FPL	0.96	0.68	1.36	0.96	0.68	1.36	0.96	0.68	1.36	0.92	0.62	1.35	0.94	0.63	1.38	0.93	0.62	1.38	0.85	0.55	1.30	0.87	0.56	1.34	0.89	0.57	1.37
Sex																												
	Female vs. Male	1.12	0.85	1.48	1.11	0.84	1.48	1.09	0.82	1.47	0.95	0.69	1.30	0.98	0.71	1.35	0.94	0.67	1.31	1.06	0.75	1.51	1.07	0.75	1.53	0.98	0.68	1.41
Currently Insured																												
	Yes vs No				1.56	1.02	2.38																1.86	1.11	3.11			
Heart Disease																												
	Yes vs No				1.77	1.16	2.69							1.81	1.12	2.91							1.73	1.05	2.84			
Smoker																												
	Ever vs Never				1.41	1.07	1.86							1.31	0.97	1.77							1.47	1.04	2.06			
Usual Source of Care																												
	Yes vs No							2.28	1.35	3.85							1.83	1.02	3.28							3.07	1.57	5.99
Delay in Care																												
	Yes vs No																0.68	0.47	0.97									
Asthma Management Plan																												
	No vs Yes							0.46	0.35	0.61							0.44	0.32	0.60							0.41	0.29	0.59
Cockroaches																												
	Yes vs No							0.58	0.38	0.88							0.54	0.33	0.87							0.59	0.36	0.97

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.

[b](Cases, Non-cases)

[c]Model 2 controlled for the following vulnerability factors: insurance status, obesity, heart disease, smoking status, and work status.

[d]Model 3 controlled for the following vulnerability factors: urban/rural, usual source of care, delay in care, onset of asthma, asthma management plan, household smoking, dog or cat in home, cockroaches in home, housing type, household crowding, diabetes, and walking.

Table 19 (Highlights). Associations between missing 2 or more days of work pollutants (O_3, PM_{10}, and $PM_{2.5}$) adjusting for vulnerability characteristics among CHIS adults with current asthma[a]

		O_3 (per 10 ppb)									PM_{10} (per 10 µg/m^3)									$PM_{2.5}$ (per 5 µg/m^3)								
		Model 1[c] (176, 1208)[b]			Model 2[d] (176, 1208)[b]			Model 3[e] (175, 1185)[b]			Model 1[c] (142, 977)[b]			Model 2[d] (142, 977)[b]			Model 3[e] (141, 957)[b]			Model 1[c] (118, 743)[b]			Model 2[d] (118, 743)[b]			Model 3[e] (118, 727)[b]		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average		1.15	0.91	1.46	1.15	0.91	1.44	1.13	0.88	1.44	1.28	1.00	1.65	1.30	1.01	1.68	1.25	0.96	1.63	1.23	0.94	1.60	1.23	0.94	1.60	1.24	0.93	1.66
Race (Ref. White)																												
	African American	3.79	2.02	7.13	3.61	1.92	6.79	3.81	1.82	7.99	3.60	1.73	7.47	3.45	1.69	7.05	3.25	1.43	7.42	4.69	2.24	9.81	4.45	2.11	9.41	5.50	2.35	12.89
	AI/AN	1.73	0.51	5.85	1.62	0.46	5.79	1.86	0.52	6.71	1.83	0.55	6.08	1.67	0.45	6.16	1.93	0.57	6.52	1.13	0.18	7.28	1.01	0.15	6.86	1.34	0.21	8.53
	Asian / PI / Other	2.06	1.07	3.97	1.98	1.01	3.87	2.18	1.11	4.30	1.15	0.49	2.68	1.05	0.46	2.42	1.14	0.47	2.78	1.74	0.82	3.70	1.69	0.78	3.64	1.92	0.91	4.05
	Latino	3.42	2.06	5.68	3.30	1.99	5.49	3.86	2.25	6.64	3.60	2.00	6.47	3.51	1.94	6.36	3.82	2.03	7.18	3.28	1.76	6.10	3.31	1.76	6.23	4.21	2.12	8.33
Poverty (Ref. ≥400%)																												
	0 - 199% FPL	0.57	0.34	0.93	0.59	0.34	1.04	0.45	0.24	0.87	0.58	0.33	1.02	0.67	0.36	1.23	0.54	0.27	1.08	0.37	0.21	0.67	0.39	0.21	0.74	0.36	0.16	0.78
	200 - 399% FPL	1.13	0.67	1.89	1.16	0.69	1.96	1.25	0.75	2.10	1.30	0.73	2.32	1.47	0.82	2.63	1.53	0.85	2.76	0.92	0.50	1.70	1.00	0.53	1.90	1.17	0.64	2.15
Sex																												
	Female vs. Male	2.26	1.39	3.68	2.14	1.31	3.51	2.05	1.24	3.40	2.14	1.25	3.65	1.99	1.16	3.40	2.13	1.20	3.80	2.23	1.24	4.03	2.11	1.15	3.88	2.18	1.18	4.03
Daily Asthma Medication																												
	No vs Yes							0.44	0.28	0.69							0.44	0.26	0.74							0.49	0.28	0.86

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.

[b](Cases, Non-cases)

[c]Model 1 also controlled for age

[c]Model 2 controlled for the following vulnerability factors: insurance status, obesity, heart disease, smoking status, and work status.

[d]Model 3 controlled for the following vulnerability factors: urban/rural, usual source of care, delay in care, onset of asthma, daily asthma medication, asthma management plan, household smoking, dog or cat in home, cockroaches in home, housing type, household crowding, diabetes, and walking.

Table 20 (Highlights). Associations between daily asthma medication and $PM_{2.5}$ adjusting for vulnerability characteristics among CHIS 2003 children with current asthma[a]

		$PM_{2.5}$ (per 5 µg/m^3) (132, 203)[b]								
		Model 1			Model 2[c]			Model 3[d]		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average		1.20	0.88	1.63	1.20	0.87	1.64	1.28	0.93	1.76
Age (Ref. 6-11)										
	≤ 6	0.89	0.40	1.99	0.89	0.40	1.99	1.04	0.46	2.36
	12 - 17	1.07	0.56	2.07	1.07	0.55	2.09	1.51	0.74	3.12
Race (Ref. White)										
	African American	1.16	0.46	2.92	1.15	0.43	3.07	1.03	0.40	2.71
	AI/AN	1.11	0.15	8.44	1.11	0.14	8.82	0.84	0.11	6.26
	Asian / PI / Other	0.92	0.34	2.49	0.97	0.36	2.60	0.86	0.32	2.29
	Latino	1.43	0.66	3.10	1.49	0.68	3.26	1.31	0.57	3.00
Poverty (Ref. ≥400%)										
	0 - 199% FPL	2.64	1.22	5.72	2.51	1.14	5.56	3.21	1.40	7.39
	200 - 399% FPL	3.00	1.46	6.14	2.86	1.40	5.87	3.56	1.66	7.60
Sex										
	Female vs. Male	0.96	0.52	1.75	0.96	0.52	1.76	0.92	0.51	1.69
Asthma Management Plan										
	No vs Yes							0.38	0.19	0.75

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b](Cases, Non-cases)
[c]Model 2 controlled for the following vulnerability factors: household smoking, dog or cat in home, cockroaches in home, and insurance status.
[d]Model 3 controlled for the following vulnerability factors: urban/rural residency, delay in care, asthma management plan, housing type, and household crowding.

Interactions between Pollutant Exposures and Vulnerability of Sub-Populations

In this part of the study, we tested the hypothesis that higher pollutant exposures interact with these vulnerability factors resulting in greater air pollution impacts on asthma in vulnerable sub-populations, i.e. racial/ethnic minorities, and low-income individuals (Hypothesis 4). We presented findings of interactions between exposure and sub-populations characterized by race/ethnicity and income.

Interactions of NO_2 with poverty

We examined the potential modifying effects of poverty on the relationships between air pollutants and asthma outcomes among current asthmatics by adding appropriate interaction terms to our regression models while adjusting for age, race, and sex. For children, in models including main effect as well as interaction variables for poverty level and NO_2, we observed a statistically significant interaction (Table 21). In children, we found that those living below 200% of the FPL had greater increases in ED visits as NO_2 annual average concentrations increased than children living at or above 400% of the FPL (p=0.01).

Interactions of PM_{10} and NO_2 with race/ethnicity

Similar to above, we created interaction terms between annual pollutant averages and race/ethnicity and included them in models with main effects for these variables. Significant interactions between NO_2 and race/ethnicity were observed (Table 22). Among adults, African Americans and Asians/PIs/Others had greater increases in missing 2 or more work days as annual average NO_2 increased (p=0.03 and p<0.01, respectively). African American adults also experienced greater increases in daily/weekly symptoms than white respondents with the same increase in annual average NO_2 (p=0.03). American Indian/Alaska Native children (p < 0.001) and Asian/PI/other children (p=0.04) showed greater increases in daily/weekly asthma symptoms than white children with the same increase in annual average NO_2.
For PM_{10}, significant interactions with race/ethnicity were found among children for two outcomes, using daily asthma medication and experiencing daily/weekly asthma symptoms (Table 23). Latino children had greater increases in daily asthma medication use compared to white children as annual average PM_{10} increased (p=0.05). Both African American children (p=0.03) and Asian/PI/other (p=0.03) children had greater increases in daily/weekly symptoms in comparison to white children with the same level of increase in PM_{10} annual average concentration.

Estimated odds in vulnerable sub-populations

Based on interaction models above we calculated odds ratios and 95% confidence intervals for sub-populations that had significant interactions with one of the pollutant measures. With regard to household FPL, in children we found that the odds of ED visits increased over two times (OR=2.14, 95% CI=1.22-3.74) per 10 ppb NO_2 in children living below 200% FPL compared to a 34% (95% CI=0.33-1.34) decrease in odds per 10 ppb NO_2 in children living at or above 400% FPL (Table 24 in Appendix).

We also estimated effects by race/ethnicity since we observed significant interactions of NO_2 exposure and race/ethnicity (Table 24 in Appendix). Among adults the odds of missing at least 2 days of work increased 86% (95% CI=0.87-3.96) among African Americans and over two and a half times (OR=2.72, 95% CI=1.32-5.61) among Asians/PIs/Others per 10 ppb NO_2 compared to an estimated 27% decrease in odds per 10 ppb NO_2 among whites. Odds of daily/weekly symptoms in adults increased over two times (OR=2.21, 95% CI=1.13-4.33) per 10 ppb NO_2 for African Americans compared to a 2% (95% CI=0.81-1.29) decrease in odds per 10 ppb NO_2 for whites. In children some racial/ethnic groups showed increased vulnerability to the effects on NO_2 on daily/weekly symptoms in our models. Specifically, we observed odds for daily/weekly symptoms increase over four and a half times (OR=4.52, 95% CI=0.57-35.52) for Asian/PI/other children per 10 ppb NO_2 compared to a 56% decrease in odds per 10 ppb NO_2 for white children. We also found a significant interaction with NO_2 for American Indians/Alaska natives, but we were not able to estimate the OR and 95% C.I. for this group due to small sample size.

The estimated effects of PM_{10} also differed by race/ethnicity in children (Table 25 in Appendix). The odds of using daily asthma medication increased 33% (95% CI=0.87-2.04) per 10 $\mu g/m^3$ PM_{10} in Latino children compared to a 26% (95% CI=0.51-1.08) decrease in odds of using daily medication per 10 $\mu g/m^3$ PM_{10} in white children. With respect to daily/weekly symptoms increased vulnerability to PM_{10} was observed for both African American children and Asian/PI/other children in comparison to white children in our models. Odds for daily weekly symptoms increased almost 2 and a half times (OR= 2.48, 95% CI=0.89-6.91) in African American children and about 2 times (OR= 2.07, 95% CI=0.93-4.60) in Asian/PI/other children per 10 $\mu g/m^3$ PM_{10} compared to a 30% (95% CI=0.41-1.17) decrease in odds in white children.

Table 21. 12-month NO_2 pollutant exposure by poverty interaction term among children with current asthma[a]

		ED Visits (Children)		
Variables		Estimate	Std Error	p-value
Intercept		-0.67	0.76	0.38
NO_2 (per 10 ppb)[b]		-0.41	0.36	0.25
Age				
(Ref. 6 - 11 year old)	0-5	0.88	0.33	0.01
	12-17	-1.70	0.42	<.0001
(Ref. ≥ 65 years old)	18-34			
	35-64			
Race (Ref. Whites)				
	African American	0.67	0.42	0.11
	AI/AN	0.65	0.93	0.48
	Asian / PI / Other	-0.61	0.55	0.27
	Latino	0.32	0.39	0.41
Poverty (Ref. ≥ 400% FPL)				
	0 - 199% FPL	-2.62	1.03	0.01
	200 - 399% FPL	0.30	0.98	0.76
Sex (Ref. Male)				
	Female	0.08	0.31	0.79
NO_2 * Poverty (0-199% FPL)		1.17	0.46	0.01
NO_2 * Poverty (200-399% FPL)		0.15	0.48	0.76

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question "do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.

[b]In this model the estimate for the pollutant term represents the estimated effect in the reference group for the interaction term, in this case ≥ 400% FPL.

Table 22. 12-month NO_2 pollutant exposure by race interaction term among adults and children with current asthma[a]

		Missed ≥ 2 Work Days (Adults)			Daily/Weekly Symptoms (Adults)			Daily/Weekly Symptoms (Children)		
Variables		Estimate	Std Error	p-value	Estimate	Std Error	p-value	Estimate	Std Error	p-value
Intercept		-4.80	1.12	<.0001	-0.69	0.31	0.03	-2.19	0.83	0.01
NO_2 (per 10 ppb)[b]		-0.32	0.22	0.15	0.02	0.12	0.85	-0.82	0.38	0.03
Age										
(Ref. 6 - 11 year old)	0-5							0.06	0.59	0.92
	12-17							0.70	0.47	0.14
(Ref. ≥ 65 years old)	18-34	2.49	1.05	0.02	-0.85	0.24	0.00			
	35-64	2.70	1.03	0.01	-0.18	0.19	0.34			
Race (Ref. Whites)										
	African American	-0.57	1.01	0.57	-1.95	0.86	0.02	-1.27	1.69	0.45
	AI/AN	-0.43	1.88	0.82	1.67	1.23	0.17	-128	6.27	<.0001
	Asian / PI / Other	-2.00	1.07	0.06	-0.68	0.75	0.37	-5.37	3.19	0.09
	Latino	0.30	0.81	0.72	0.48	0.68	0.49	-1.77	1.17	0.13
Poverty (Ref. ≥ 400% FPL)										
	0 - 199% FPL	-0.68	0.28	0.02	0.49	0.19	0.01	1.21	0.54	0.03
	200 - 399% FPL	-0.04	0.29	0.88	-0.01	0.21	0.95	1.33	0.52	0.01
Sex (Ref. Male)										
	Female	0.80	0.28	<0.01	0.13	0.17	0.44	0.24	0.42	0.57
NO_2 * Race (African American)		0.94	0.44	0.03	0.77	0.36	0.03	0.77	0.78	0.33
NO_2 * Race (AI/AN)		0.44	0.84	0.60	-1.12	0.78	0.15	50.4	2.43	<.0001
NO_2 * Race (Asian/PI/Other)		1.32	0.43	0.00	0.26	0.32	0.42	2.33	1.13	0.04
NO_2 * Race (Latino)		0.50	0.34	0.14	-0.49	0.28	0.08	0.98	0.53	0.06

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b]In this model the estimate for the pollutant term represents the estimated effect in the reference group for the interaction term, in this case White.

Table 23. 12-month PM_{10} pollutant exposure by race interaction term among children with current asthma[a]

		Daily Asthma Medication (Children)			Daily / Weekly Symptoms (Children)		
Variable		Estimate	Std Error	p-value	Estimate	Std Error	p-value
Intercept		-0.99	0.60	0.10	-1.47	0.81	0.07
PM_{10} (per 10 μg/m^3)[b]		-0.30	0.19	0.12	-0.36	0.27	0.17
Age (Ref. 6-11 years old)							
	0-5	0.25	0.39	0.52	0.28	0.63	0.66
	12-17	-0.23	0.30	0.45	0.15	0.45	0.74
Race (Ref. Whites)							
	African American	-1.11	1.57	0.48	-4.11	2.06	0.05
	AI/AN	1.20	2.16	0.58	-15.50	1.38	<.0001
	Asian / PI / Other	1.96	1.31	0.13	-4.26	1.54	0.01
	Latino	-0.97	0.96	0.31	0.64	1.25	0.61
Poverty (Ref. ≥ 400% FPL)							
	0 - 199% FPL	0.81	0.35	0.02	0.41	0.50	0.40
	200 - 399% FPL	1.05	0.33	0.00	0.79	0.43	0.07
Sex (Ref. Male)							
	Female	0.57	0.28	0.04	-0.06	0.43	0.90
PM_{10} * Race (African American)		0.63	0.52	0.23	1.27	0.57	0.03
PM_{10} * Race (AI/AN)		-0.55	0.67	0.41	0.34	0.45	0.45
PM_{10} * Race (Asian/PI/Other)		-0.74	0.45	0.10	1.09	0.49	0.03
PM_{10} * Race (Latino)		0.58	0.30	0.05	-0.31	0.44	0.48

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b]In this model the estimate for the pollutant term represents the estimated effect in the reference group for the interaction term, in this case White.

CHIS 2003 Respondents with Asthma-like Symptoms

Exposure distributions for CHIS 2003 respondents with asthma-like symptoms

Distributions of annual average criteria pollutant exposures, exceedance days, and traffic density for CHIS 2003 respondents with asthma-like symptoms are shown in Table 26 in the Appendix. Among adults, annual average O_3 exposure ranged from 22.9-65.7 ppb, with a mean of 41.7 ppb. Annual average exposure to PM_{10} ranged from 7.9- 82.8 μg/m^3, with a mean of 30.1 μg/m^3, and annual average exposure to $PM_{2.5}$ ranged from 4.1-26.9 μg/m^3 with a mean of 16.5 μg/m^3. Annual average exposure to NO_2 ranged from 1.4-36.1 ppb, with a mean of 22.0 ppb.

On average, adults experienced 23.6 days when maximum 1-hr O_3 concentrations exceeded the 1-hr state standard (range of 0-131 days), 32.1 days when the maximum 8-hr O_3 concentration exceeded the 8-hr state standard (range 0-160 days) and 17.7 days when the maximum 8-hr O_3 concentration exceeded the 8-hr federal standard (range of 0-130 days). Adult 24-hr averages for PM_{10} rarely exceeded the federal standard (mean=0.10 days, range 0-4 days), but averages more frequently exceeded the state standard (mean=8.2 days, range 0-66 days). Adults experienced an average of 16.1 days when $PM_{2.5}$ levels exceeded the federal standard (range of 0-54 days).

Adults with asthma-like symptoms had a mean traffic density of 65.8 VMT/day/$meters^2$, with a minimum of 1.0 and a maximum of 745.4. Among children with asthma-like symptoms, annual average exposures to O_3 ranged from 22.9-63.5 ppb, with a mean of 42.1 ppb. Annual average PM_{10} exposure ranged from 12.8-82.8 μg/m^3 (mean=29.9 μg/m^3), and annual average $PM_{2.5}$ exposure ranged from 6.6-26.3 μg/m^3 (mean=16.5 μg/m^3). Annual averages for NO_2 ranged from 5.0-36.0 ppb, with a mean of 22.3 ppb.

Children with asthma-like symptoms had a mean of 24.6 O_3 exceedance days based on the 1-hr state standard (range 0-122 days), a mean of 33.9 exceedance days based on the 8-hr state standard (range of 0-153 days), and a mean of 18.6 exceedance days based on the 8-hr federal standard (range 0-114 days) in the year prior to the CHIS interview. Under the federal PM_{10} standard, children with asthma-like symptoms had a maximum of 4 exceedance days and an average of 0.12 exceedance days; under the state PM_{10} standard, they had a maximum of 64 exceedance days and an average of 7.9 exceedance days. The maximum number of $PM_{2.5}$ exceedance days was 54 days, with a mean of 16.6. Traffic density exposure ranged from 0.5-637.2 VMT/day/$meters^2$, with a mean of 64.1, among children with asthma-like symptoms. Frequencies for distance to roadway measures among adults and children with asthma-like symptoms are shown in Table 27 in the Appendix. Among adults with asthma-like symptoms, 6.1% lived within 300 meters of a state highway, and 10.4% lived within 300 meters of an interstate highway. One-fifth (19.7%) of adults with asthma-like symptoms lived within 50 meters of a major road. Among children with asthma-like symptoms, 5.3% lived within 300 meters of a state highway, and 10.8% lived within 300 meters of an interstate highway. Close to one-fifth (17.8%) lived within 50 meters of a major road.

Correlations among air pollutant exposure estimates

Table 28 in the Appendix shows Pearson correlation coefficients for exposure metrics among CHIS 2003 respondents with asthma-like symptoms. Annual average exposure estimates for PM_{10} and $PM_{2.5}$ were strongly positively correlated (r=0.74), as were estimates for $PM_{2.5}$ and NO_2 (r=0.71). PM_{10} annual averages were moderately correlated with O_3 and NO_2 (r=0.48 and r=0.50). State and federal O_3 exceedance measures had strong positive correlations with annual average O_3 exposure (r≈0.8) and moderate correlations with annual average PM_{10} exposure (r≈0.6). Annual average PM_{10} exposure was highly correlated with PM_{10} state standard exceedances (r=0.83). Exceedances of the PM_{10} state standard were moderately correlated with exceedances of state and federal standards for O_3 (r≈0.6). Moderate to low correlations were observed between annual average exposures and exceedance measures across the other pollutants. No correlations were observed between traffic density or distance to roadway measures and the criteria pollutant exposure metrics or with each other.

Health outcomes and characteristics of adults and children with asthma-like symptoms

Table 29 shows health outcomes among respondents without an asthma diagnosis who reported asthma-like symptoms and had lived in the same home or neighborhood for at least 9 months prior to being interviewed. Among adults without an asthma diagnosis, 11.5% reported symptoms described as wheeze, and nearly two-thirds (62.0%) had experienced two or more wheeze attacks within the past year. Additionally, 16.8% had missed at least two days of work, and 41.3% had sought medical help for wheezing.

Among children without an asthma diagnosis, 9.9% had experienced wheezing, and over half (51.7%) had suffered two or more wheeze attacks. Close to half (45.4%) had missed at least two school days, and almost two-thirds (65.5%) had sought medical help due to wheezing.

Table 29. Prevalence of asthma-like outcomes for CHIS 2003 adults and children without an asthma diagnosis[a]

	Adults (≥18 years)		Children (< 18 years)	
Outcome	n	% (Weighted)	n	% (Weighted)
Wheeze	4,129	11.5	951	9.9
Missed ≥ 2 Work/ School Days[b]	510	16.8	313	45.4
Wheeze Attacks (2 or more)[b]	2,313	62.0	324	51.7
Sought Medical Help for Wheezing (1 or more)	1,497	41.3	643	65.5

[a]For CHIS 2003, having asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived in the same home or neighborhood for at least 9 months were included.
[b]Data not collected for teen respondents.

Asthma-like symptoms were reported in nearly the same percentage of male adults as female, 50.5% vs. 49.5% respectively (Table 30 in Appendix). More than half of adult respondents with asthma-like symptoms were between 35-64 years old (56.4%), 28.3% were 18-34 years old, and 15.3% were 65 years old or older. The racial/ethnic distribution of the adult population with asthma-like symptoms was as follows: 58.5% white, 23.0% Latino, 9.5% Asian/other, 6.7% African American, and 2.3% American Indian/Alaska Native.

Among adults with asthma-like symptoms, 43.3% had a high school education or less. More than a third (37.8%) had completed college or a vocational school, and 8.6% had a graduate degree. The remaining 10.3% were 25 years old or younger; for these respondents, educational attainment was not assessed. More than one-third (39.0%) of adults with asthma-like symptoms lived below 200% of the FPL, and 24.7% lived between 200-399% of the FPL. Close to one-third (36.4%) of adult respondents with asthma-like symptoms had an income ≥400% of the FPL. Nearly a third (32.5%) of adults with asthma-like symptoms were unemployed.

Approximately one-fourth (24.5%) of adults with asthma-like symptoms were not insured or were only insured for part of the year. Similarly, 16.2% of these adults reported that they did not have a usual source of care, and 25.8% of adults reported a delay in needed care for any medical reason in the last 12 months. Nearly a quarter (24.5%) of adults reported visiting the doctor six or more times for any reason in the last year, and 41.8% of adults visited the doctor between two and five times for any reason in the past year. The remaining third (33.8%) had visited the doctor 0-1 time for any reason in the past year.

When self-reporting health status, 35.8% of adults with asthma-like symptoms reported poor or fair health as compared to 64.2% who reported good, very good, or excellent health. Heart disease was reported in 11.3%, and 41.3% of those reported congestive heart failure. Based on BMI, 62.5% of adults were classified as overweight/obese as opposed to normal or underweight.

More than half (59.3%) of adults were currently smoking or had been smokers in the past, though only 17.1% reported smokers living in the home. More than two-thirds (68.9%) of adult respondents reported walking for transportation or leisure. Dogs and/or cats lived in the home with 43.3% of adult respondents. Cockroaches were reported in the home for 20.3% of adults.

The majority (43.7%) of adult respondents with asthma-like symptoms lived in urban residences. Among those remaining, 26.2% lived in 2nd city locations, 16.3% in the suburbs, and 13.7% in towns or areas designated as rural. Most adults (80.4%) with asthma-like symptoms had lived at their residences for three years or more. Household crowding was reported for 23.5% of adults. The majority (63.1%) of adults with asthma-like symptoms lived in houses, and the remainder lived in apartments, duplexes, or mobile homes.

In children with asthma-like symptoms, slightly more boys reported experiencing wheezing (54.9%) as compared to girls (45.1%). Children ages 0-5 composed 41.2% of child respondents with asthma-like symptoms, 28.5% were ages 6-11, and the remaining 30.3% were ages 12-17. Children with asthma-like symptoms were 42.6% white, 34.3% Latino, 14.7% Asian/other, 7.4% African American, and 1.1% American Indian/Alaska Native.

The majority of children with asthma-like symptoms lived in households in which the adult who had responded on their behalf had either a college education (46.3%) or a high school education or less (42.8%). Eleven percent lived in households in which the adult respondent had completed graduate school. Forty-two percent of children with asthma-like symptoms lived below 200% of the FPL, 23.6 percent lived in households between 200-399% of the FPL, and the remaining 34.0% lived at or above 400% of the FPL.

Though the majority of children with asthma-like symptoms were insured, 10.1% of children were not insured or were only insured for part of the year, 10.6% of children reported that they did not have a usual source of care, and 12.3% of children reported a delay in needed care for any medical reason in the last 12 months. Fifteen percent of children reported visiting the doctor six or more times for any reason in the last year, and 60.0% of children visited the doctor between two and five times for any reason in the past year. A quarter (25.0%) had visited the doctor one time or less for any reason in the last year.

Among children with asthma-like symptoms, 13.5% self-reported poor or fair health. Among respondents below the age of 18, BMI was assessed for teenage respondents only. For teens with asthma-like symptoms 25.5% were classified as overweight/obese.

The percentage of children with smokers living in the home was 7.1%. Dogs and/or cats within the home were reported for 38.2% of child respondents. A quarter (25.3%) of children with asthma-like symptoms reportedly also had cockroaches in the home.

Most (42.5%) child respondents with asthma-like symptoms lived in urban residences, compared to 25.0% of children who lived in 2nd city locations, 20.3% in the suburbs, and 12.2% in towns or rural areas. Sixty-two percent of children with asthma-like symptoms had lived at their residences for three years or more. Household crowding was reported for more than a third (37.3%) of children with asthma-like symptoms. Most children with asthma-like symptoms lived in houses (68.8%), while the remainder lived in apartments, duplexes or mobile homes.

Disparities in Asthma-like Symptoms and Exposure Measures among Sub-Populations

In this part of the study, we tested Hypothesis 1: Vulnerable sub-populations in California (e.g., racial/ethnic minorities and low-income individuals) have higher exposures to air pollution. We presented differences in estimated criteria pollutant exposures across various sub-populations, characterized by rural and urban residency, age, gender, income level, and by racial and ethnic group. We also presented results regarding differences in distributions of asthma-like symptoms across these subgroups.

Disparities in Annual Average Criteria Pollutant Exposure Measures

We observed differences in mean annual average criteria pollutant exposures for CHIS respondents with asthma-like symptoms according to demographic characteristics (Table 31 in Appendix). In comparison to those living at or above 400% of the FPL, adult respondents with asthma-like symptoms living below 200% of the FPL had higher average annual exposure to three of the four criteria pollutants. The mean annual average NO_2 level was 23.3 ppb for those living below 200% of the FPL, compared to 21.1 ppb for those living at or above 400% of the FPL. The mean annual average PM_{10} level was 32.4 µg/m^3 for those living below 200% of the FPL, compared to 29.5 µg/m^3 for those living at or above 400% of the FPL. A dose-response relationship was observed between poverty level and annual average $PM_{2.5}$ exposure. Individuals living at or above 400% of the FPL had a mean exposure of 15.3 µg/m^3, which increased to 16.4 µg/m^3 among those living between 200-399% of the FPL and 17.4 µg/m^3 for those living at less than 200% of the FPL.

When comparing exposures across ethnicities, we observed that Latino adult respondents had higher mean exposures to NO_2 (24.3 ppb vs. 20.5 ppb), PM_{10} (33.7 µg/m^3 vs. 28.6 µg/m^3), and $PM_{2.5}$ (18.2 µg/m^3 vs. 15.7 µg/m^3) than white adult respondents. Mean annual average NO_2 exposures were also higher among African Americans than whites (23.3 ppb vs. 20.5 ppb); however white respondents had higher mean annual O_3 concentrations than African Americans (42.4 ppb vs. 38.9 ppb).

Mean annual average NO_2 levels were highest among urban dwellers (24.7 ppb), compared to 2nd city (18.4 ppb), suburban (19.8 ppb), and town/rural (11.0 ppb) dwellers.

However, as residential distance from city centers increased, so did annual average O_3 exposure. Urban dwellers had the lowest annual average O_3 exposure at 38.8 ppb, versus 44.2 ppb for 2^{nd} city, 44.7 ppb for suburban, and 48.1 ppb for town/rural dwellers. Urban dwellers also had lower annual average PM_{10} levels than both 2^{nd} city and suburban dwellers (29.2 µg/m^3 vs. 30.7 µg/m^3 and 33.0 µg/m^3, respectively). Adults living in urban residences had higher annual average $PM_{2.5}$ levels (16.6 µg/m^3) than those living in town/rural residences (10.1 µg/m^3), but lower levels than those living in suburban residences (17.7 µg/m^3). Adult females had higher average annual PM_{10} concentrations at 30.7 µg/m^3, compared to 29.3 µg/m^3 among males.

Among children with asthma-like symptoms, individuals living between 200-399% of the FPL had slightly higher annual average NO_2 levels than children living at or above 400% of the FPL (20.8 ppb vs. 20.3 ppb). Compared to white children, Latino and African American children had higher mean annual average levels of NO_2 (19.3 ppb vs. 24.8 ppb and 24.0 ppb, respectively). Latino children also had higher mean annual average concentrations of PM_{10} than white children (32.6 µg/m^3 vs. 28.6 µg/m^3).

Children living in urban residences had the highest annual average NO_2 levels at 25.6 ppb, compared to 18.0 ppb among 2^{nd} city residents, 19.9 ppb suburban residents, and 18.8 ppb among town/rural residents. Conversely, urban children had the lowest mean annual O_3 exposure at 39.0 ppb, as opposed to 44.2 ppb among 2^{nd} city children, 45.3 ppb among suburban children, and 47.7 ppb among town/rural children. Suburban children had higher annual average PM_{10} concentrations than urban children (33.9 µg/m^3 vs. 29.0 µg/m^3). Urban children had higher $PM_{2.5}$ annual average concentrations at 16.8 µg/m^3, compared to 2^{nd} city and town/rural children at 14.6 µg/m^3 and 9.2 µg/m^3, respectively.

Disparities in asthma-like symptoms

Asthma-like symptoms were not equally reported across all demographic characteristics. A linear association was observed between prevalence of wheezing and household federal poverty level. Among adults, 9.8% of those living at 400% or greater than the FPL, 11.7% of those living between 200-399% of the FPL, and 13.4% of those living below 200% of the FPL reported wheezing (Table 32 in Appendix).

When comparing asthma-like outcomes across races/ethnicities, Alaskan Natives/American Indians had the highest prevalence of wheeze (26.4%), more than twice the prevalence than that of white adults (13.1%). However, Latino and Asian/Pacific Islander respondents had lower prevalence of wheezing compared to white respondents, at 9.8% and 7.2%, respectively. Nearly a quarter (24.5%) of Latino respondents reported missing ≥2 days of work, compared to 14.3% of whites, and nearly half (46.1%) sought medical help at least once because of breathing problems, compared to 38.5% of whites. Additionally, just over half (51.7%) of Latino respondents reported having 2 or more wheeze attacks, although comparatively more white respondents reported 2 or more wheeze attacks (64.8%). Forty-nine percent of African Americans sought medical help for a breathing problem compared to 38.5% of whites.

A higher percentage of adult respondents living in 2^{nd} city (12.2%) or town/rural (14.4%) residences reported experiencing wheezing as compared to their urban counterparts (11.0%). More female adult respondents reported missing at least 2 days of work (20.3%) and seeking medical help at least once due to breathing problems (50.3%) compared to males (13.6% and 32.8%).

More adults between the ages of 18-34 (18.3%) and 35-64 (17.0%) reported missing at least 2 days of work. Adult respondents in the oldest age bracket (≥65, 48.6%) had a higher prevalence of seeking medical help due to breathing problems than adult respondents in the lowest age bracket (18-34, 35.5%).

Among child respondents with asthma-like symptoms, Asians/Pacific Islanders/Others reported a higher prevalence of ≥2 wheeze attacks in the last year, at 75.5% compared to 48.1% among white children, but they reported a lower prevalence of missing at least 2 days of school due to wheezing (29.6% vs. 45.5%). The prevalence of wheezing was greater amongst boys than girls (10.9% vs. 8.9%). Fourteen percent of children ages 0-5 were reported to experience wheezing, compared to 8.4% of children ages 12-17. As children got older, the prevalence of seeking medical help at least once in the last year because of breathing problems decreased. The prevalence of seeking medical attention due to breathing problems was 82.8% in children ages 0-5, 73.6% in children ages 6-11, and 34.2% in children ages 12-17.

Associations between air pollution exposure metrics and asthma-like symptoms

In this part of the study, we tested Hypothesis 2 that individuals with asthma-like symptoms and exposed to higher levels of air pollution are more likely to report: wheezing or whistling sound in the chest, attacks of wheezing or whistling (Hypothesis 2). We presented results of crude associations (Crude Odds Ratio) between individual air pollutants and asthma-like symptoms using tabular analyses and logistic regression modeling adjusting for age, sex, race/ethnicity and federal poverty level (Adjusted Odds Ratio).

Associations between 12-month pollutant averages and asthma-like symptoms

Among adults with asthma-like symptoms, a 10 ppb increase in annual average O_3 concentration was associated with a 9% (95% CI=1.01-1.18) increase in odds of reporting wheeze and an 11% increase in odds of reporting 2 or more wheezing attacks (95% CI=0.94-1.30, Table 33). A 10 $\mu g/m^3$ increase in PM_{10} annual averages was associated with a 9% increase in wheeze (95% CI=1.01-1.18), a 10% increase in odds of reporting ≥2 wheeze attacks (95% CI=0.94-1.29), and a 9% (95% CI=0.94-1.27) increase in seeking medical help in the past year. A 5 $\mu g/m^3$ increase in $PM_{2.5}$ annual averages was associated with a 7% (95% CI=0.97-1.17) increase in odds of reporting wheeze. The odds of missing ≥2 days of work due to wheezing appeared to decrease with increasing NO_2 exposure (OR=0.73, 95% CI=0.56-0.96).

Among children with asthma-like symptoms, a 10 ppb increase in O_3 annual averages was associated with a 9% (95% CI=0.92-1.29) suggested increase in odds of wheeze and a 29% (95% CI=0.92-1.81) suggested increase in the likelihood of reporting 2 or more wheeze attacks. A 10 ppb increase in NO_2 was suggested to increase the odds of seeking medical help due to breathing problems by 33% (95% CI=0.90-1.98).

Table 33 (Highlights). Associations (OR (95% CI)) for 12-month pollutant averages and asthma-like outcomes in CHIS 2003 adults and children with asthma-like symptoms[a]

	Wheeze				Missed ≥2 School/Work Days Due to Wheezing[b]				≥2 Wheeze Attacks[b]				Sought Medical Help for Breathing Problem			
Pollutant	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.
Adults																
O_3 (per 10 ppb)	2,044	14,824	**1.09**	[1.01, 1.18]	258	1,296	0.91	[0.74, 1.12]	1,121	657	1.11	[0.94, 1.30]	739	1,039	1.06	[0.91, 1.24]
PM_{10} (per 10 μg/m^3)	1,614	11,229	**1.09**	[1.01, 1.18]	198	1,027	0.84	[0.66, 1.06]	912	488	1.10	[0.94, 1.29]	577	823	1.09	[0.94, 1.27]
$PM_{2.5}$ (per 5 μg/m^3)	1,253	9,331	1.07	[0.97, 1.17]	162	797	0.88	[0.69, 1.12]	691	396	1.00	[0.83, 1.19]	462	625	1.06	[0.89, 1.26]
NO_2 (per 10 ppb)	1,687	12,534	0.93	[0.86, 1.02]	222	1,061	0.73	[0.56, 0.96]	905	566	1.09	[0.91, 1.30]	622	849	0.93	[0.78, 1.11]
Children																
O_3 (per 10 ppb)	441	4,109	1.09	[0.92, 1.29]	143	167	0.96	[0.67, 1.36]	157	153	1.29	[0.92, 1.81]	295	146	0.99	[0.72, 1.36]
NO_2 (per 10 ppb)	364	3,504	0.94	[0.79, 1.11]	113	146	1.25	[0.82, 1.90]	134	125	1.02	[0.69, 1.50]	243	121	1.33	[0.90, 1.98]

[a]For CHIS 2003, having asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b]Data not collected for teen respondents.
[c]Adjusted for age, race, poverty level, and sex.

Associations for annual days exceeding air pollution standards and asthma-like symptoms

Adults who experienced ≥51.2 days when maximum 8-hr O_3 concentrations exceeded the 8-hr state standard had an estimated 16% (95% CI=0.97-1.38) increase in odds of reporting wheeze in the previous year, compared to adults with <1.9 exceedance days (Table 34 in Appendix). Adults with 14.3-<51.2 days when maximum 8-hr O_3 concentrations exceeded the state standard had estimated odds increases of 42% (95% CI=0.99-2.04) for reporting ≥2 wheeze attacks in the previous year compared to adults with <1.9 exceedance days, but those with ≥51.2 exceedance days had only a 30% increase (95% CI=0.91-1.87). Adults who experienced ≥6.6 days with PM_{10} concentrations exceeding the state standard had estimated odds increases for wheeze of 26% (95% CI=1.04-1.53).

Children with asthma-like symptoms experiencing 0.8-<8.7 or ≥36.7 days when maximum 1-hr O_3 concentrations exceeded the 1-hr state standard were nearly 3 (OR=2.79, 95% CI=1.10-7.10) or 4 (OR=3.98, 95% CI=1.56-10.11) times more likely, respectively, to have experienced ≥2 wheeze attacks in the last year than their peers with <0.8 exceedance days (Table 34 in Appendix). Children with maximum 8-hr O_3 concentrations exceeding the state standard 1.9-<14.3 or ≥51.2 O_3 days had a 34% (95% CI=0.92-1.96) or 32% (95% CI=0.91-1.91) suggested increase in odds of experiencing wheezing in comparison to those with <1.9 exceedance days. Children with 14.3-<51.2 days exceeding the 8-hr O_3 state standard were also more than twice as likely to miss 2 or more days of school due to wheezing (OR=2.35, 95% CI=1.01-5.47), but those with ≥51.2 days were not at increased odds. In general, the exposure-response patterns for the exceedance day measures and wheeze outcomes were not consistent in children.

Associations for traffic density/distance to roadway and asthma-like symptoms

We observed few consistent associations between residence-based measures of traffic and wheeze outcomes in adults (Table 35 in Appendix). Adults with traffic density exposures in the 2nd and 3rd exposure quartiles were 23% (95% CI=0.94-1.62) and 30% (95% CI=0.99-1.71) more likely to report seeking medical help in the last year due to breathing problems compared to those in the lowest exposure quartile, however those in the highest TD exposure quartile did not appear to have increased odds.

We also did not observe consistent associations between traffic density and wheeze outcomes in children (Table 35 in Appendix). Children with asthma-like symptoms and living within 300 m of an interstate highway had two and a half times greater odds of ≥2 wheeze attacks (OR=2.55, 95% CI=1.16-5.57), and those living within 50 m of a major road had 73% (95% CI=0.98-3.07) greater odds of missing ≥2 days of school due to wheezing compared to children living farther from these roadways.

Pollutant and Asthma-like Symptom Relationships after Adjusting for Vulnerability (Confounding) Factors

In this part of the study, we tested hypothesis if air pollution exposures, low SES status, and certain vulnerability factors associated with low SES exert independent adverse effects on individuals with asthma-like symptoms (Hypothesis 3). We presented findings multiple logistic regression results regarding associations between air pollution exposures and outcomes after including and excluding suspected confounders, such as insurance status, cigarette smoking, and delays in care.

Associations between 2 or more wheeze attacks and O_3, adjusting for vulnerability factors in adults

Under the base model, adults with asthma-like symptoms had an 11% (95% CI=0.94-1.30) suggested increase in the odds of having ≥2 wheeze attacks in the year prior to the interview as O_3 annual average concentration increased by 10 ppb (Table 36). The suggested positive relationship between having ≥2 wheeze attacks and O_3 was upheld under Model 2 (OR=1.12, 95% CI=0.95-1.32) and Model 3 (OR=1.12, 95% CI=0.95-1.31).

No other positive associations were observed under Model 1; however, the model demonstrated decreased odds for Latino respondents versus white respondents (OR=0.56, 95% CI=0.39-0.78). The similar effect of being Latino was also evidenced under Model 3. Positive associations were observed between having two or more wheeze attacks and other vulnerability factors in Models 2 and 3. Under Model 2, respondents ages 35-64 had 63% (95% CI=1.08-2.44) greater odds than respondents 65 or older, and those who had ever smoked were 43% (95% CI=1.08-1.88) more likely to report ≥2 wheeze attacks in the last year than those who had never smoked. Employed respondents were less likely than unemployed respondents to have had ≥2 wheeze attacks in the last year (OR=0.52, 95% CI=0.37-0.73). Under Model 3, having a delay in care (OR=0.58, 95% CI=0.43-0.80) and the absence of household smoking (OR=0.54, 95% CI=0.37-0.79) had protective associations with having ≥2 wheeze attacks in the past year.

Associations between 2 or more wheeze attacks and O_3, adjusting for vulnerability factors in children

Among children with asthma-like symptoms, the odds of having ≥2 wheeze attacks had a suggested increase of 29% (95% CI=0.90-1.84) as annual average O_3 concentration increased by 10 ppb under the base model (Table 37). Under Models 2 and 3, the suggested association between ≥2 wheeze attacks and O_3 was maintained (OR=1.28, 95% CI=0.89-1.83 and (OR=1.27, 95% CI=0.86-1.89, respectively).

Under Model 1, an exposure-response relationship was observed between having ≥2 wheeze attacks and poverty level. Children living between 200-399% of the FPL had over twice greater odds (OR=2.42, 95% CI=1.06-5.55) and children living below 200% of the FPL had over three times greater odds (OR=3.44, 95% CI=1.60-7.38) of having ≥2 wheeze attacks as children living at or above 400% of the FPL. Under Models 2 and 3, the exposure-response relationship with poverty level persisted.

Table 36 (Highlights). Associations between two or more wheeze attacks and O_3 adjusting for vulnerability characteristics among CHIS adults with asthma-like symptoms[a]

		Model 1 (1121, 657)[b]			Model 2[c] (1115, 652)[b]			Model 3[d] (1105, 647)[b]		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
O_3 12-Month Average (per 10 ppb)		1.11	0.94	1.30	1.12	0.95	1.32	1.12	0.95	1.31
Age (Ref. ≥65)										
	18 - 34	0.85	0.57	1.27	1.17	0.72	1.88	0.63	0.40	0.98
	35 - 64	1.22	0.86	1.72	1.63	1.08	2.44	0.98	0.68	1.41
Race (Ref. White)										
	African American	0.94	0.57	1.54	0.97	0.59	1.62	1.05	0.62	1.77
	AI/AN	1.83	0.73	4.59	2.00	0.78	5.17	1.85	0.72	4.79
	Asian / PI / Other	1.02	0.63	1.65	1.08	0.67	1.73	1.07	0.64	1.78
	Latino	0.56	0.39	0.78	0.57	0.39	0.82	0.64	0.44	0.94
Poverty (Ref. ≥400%)										
	0 - 199% FPL	1.05	0.76	1.45	0.82	0.58	1.17	0.98	0.69	1.40
	200 - 399% FPL	0.92	0.67	1.27	0.84	0.60	1.16	0.86	0.62	1.19
Sex										
	Female vs. Male	0.99	0.76	1.28	0.96	0.73	1.26	0.94	0.71	1.23
Work Status										
	Employed vs Unemployed				0.52	0.37	0.73			
Delay in Care										
	Yes vs No							0.58	0.43	0.80
Household Smoking										
	No vs Yes							0.54	0.37	0.79

[a]For CHIS 2003, asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b](Cases, Controls)
[c]Model 2 used the following vulnerability factors: insurance status, obesity, heart disease, smoking status, and work status.
[d]Model 3 used the following vulnerability factors: urban/rural, usual source of care, delay in care, household smoking, dog or cat in home, cockroaches in home, household type, household crowding, diabetes, walking

Table 37 (Highlights). Associations between two or more wheeze attacks and vulnerability characteristics by O_3 among CHIS children with asthma-like symptoms[a]

		O_3 (per 10 ppb) (157, 153)[b]								
		Model 1			Model 2[c]			Model 3[d]		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Average		1.29	0.90	1.84	1.28	0.89	1.83	1.27	0.86	1.89
Age (Ref. 6-11 years)										
	< 6 years old	0.66	0.35	1.25	0.69	0.37	1.29	0.65	0.34	1.25
Race (Ref. White)										
	African American	0.32	0.06	1.69	0.26	0.04	1.60	0.38	0.08	1.81
	AI/AN	0.21	0.03	1.54	0.18	0.03	1.16	0.16	0.02	1.53
	Asian / PI / Other	2.07	0.77	5.57	1.84	0.69	4.91	2.55	0.88	7.41
	Latino	0.53	0.25	1.15	0.46	0.20	1.07	0.75	0.34	1.65
Poverty (Ref. ≥400%)										
	0 - 199% FPL	3.44	1.60	7.38	3.62	1.59	8.23	4.88	2.05	11.63
	200 - 399% FPL	2.42	1.06	5.55	2.40	1.06	5.47	2.61	1.10	6.23
Sex										
	Female vs. Male	0.93	0.52	1.69	0.88	0.49	1.59	0.93	0.49	1.75
Household Crowding										
	No vs Yes							2.32	1.02	5.27

[a]For CHIS 2003, asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b](Cases, Controls)
[c]Model 2 used the following vulnerability factors: household smoking, dog or cat in home, cockroaches in home, and insurance status
[d]Model 3 used the following vulnerability factors: urban/rural, delay in care, housing type, and household crowding

Sensitivity Analyses

We performed analyses stratifying on: (1) length of residence in the same neighborhood, (2) employment status in adults, and (3) residential distance to nearest monitoring station (3-, 5- and 10- miles). Although associations between annual average O_3 exposure and odds of reporting asthma attacks in the previous year were similar for adults residing in the same neighborhood for <3 versus ≥3 years, associations between annual average O_3 and $PM_{2.5}$ exposure and odds of reporting daily asthma medication use in adults appeared isolated to individuals residing in the same neighborhood for at least 3 years (Table 38). In children, associations between annual average NO_2 and odds of daily asthma medication use also appeared isolated to longer-term residents (≥3 years). However, the sample size for respondents residing <3 years in the same neighborhood were smaller and the 95% confidence intervals for all point estimates overlapped widely.

Table 38. Association (OR (95% C.I.)) between asthma outcomes and 12-month pollutant exposures for CHIS 2003 adults and children with current asthma stratified by length of residence[a,b]

	Health Outcome	Pollutant	Lived in Neighborhood < 3 Years Cases	Non-Cases	OR[c]	95% C.I.	Lived in Neighborhood ≥ 3 years Cases	Non-Cases	OR[c]	95% C.I.
Adults										
	Asthma Attack[b]									
		O_3	179	259	1.22	[0.90, 1.61]	786	1,323	1.20	[1.04, 1.39]
	Daily Asthma Medication									
		O_3	120	171	0.99	[0.70, 1.40]	695	631	1.28	[1.07, 1.54]
		$PM_{2.5}$	77	97	0.99	[0.64, 1.52]	417	399	1.36	[1.10, 1.67]
Children										
	Daily Asthma Medication									
		NO_2	35	72	1.21	[0.62, 2.35]	136	226	1.50	[1.05, 2.15]

[a]For CHIS 2003 current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same neighborhood for at least 9 months were included.
[b]Respondents ever diagnosed with asthma who lived within 5 miles of an air monitoring station and in the same home or neighborhood for at least 9 months were included.
[c]Adjusted for age, race, poverty level, and sex.

When stratifying on employment status, the association between annual average PM_{10} and odds of ED visits in adult asthmatics appeared isolated to employed individuals (Table 39). This was the opposite of our prior expectation, assuming residence-based exposure measures are less misclassified for unemployed individuals who spend more time at home and that this misclassification is non-differential. One possible explanation for this finding is that employed individuals have other risk factors (e.g., co-morbidities, obesity) which make them more susceptible to the effects of PM_{10}. Or associations in employed individuals may reflect, in part, time spent commuting, since in-vehicle air pollution exposures have been shown to be higher than ambient exposures (Fruin et al., 2004, Westerdahl et al., 2005, Zhu et al., 2007).

Table 39. Association (OR (95% C.I.)) between asthma outcomes and PM_{10} pollutant for CHIS 2003 adults with current asthma stratified by employment status[a]

		Employed Cases	Non-Cases	OR[b]	95% C.I.	Unemployed Cases	Non-Cases	OR[b]	95% C.I.
PM_{10}									
	ED Visits	107	641	1.44	[1.10, 1.89]	105	444	1.01	[0.78, 1.33]

[a]For CHIS 2003 current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same neighborhood for at least 9 months were included.
[b]Adjusted for age, race, poverty level, and sex.

Additionally, since we had address information for most respondents, we were able to examine the influence of residential distance from the monitoring station on our study results. Specifically, we ran logistic regression models for the outcome of ED visits for respondents living within 3-, 5-, and 10-miles of an air monitoring station for each pollutant (Table 40). For adults, the point estimates for annual average PM_{10} and $PM_{2.5}$ were higher for the 3- and 5-mile linkage distances, while odds ratio estimates for annual average O_3 followed the opposite pattern, but 95% CIs overlapped widely in all cases. The most marked difference in odds ratio point estimates across linkage distances was observed for annual average NO_2, with the highest association observed in adults living within 3 miles of a monitoring station. In children, crude odds ratio estimates for all pollutants were greater for individuals residing within 3 miles of a monitoring station, however, these patterns did not persist for $PM_{2.5}$ and NO_2 in adjusted models and 95% CIs for all associations were wide due to the smaller sample sizes available.

Table 40. Association (OR (95% C.I.)) between ED visits and 12-month pollutant exposures for 3-, 5-, and 10-mile linkage distances to monitors for CHIS 2003 adults and children with current asthma[a]

		Adults (≥18 years old)						Children (<18 years old)					
Exposure	Distance to Station (miles)	Cases (n)	Non-cases (n)	Crude OR	95% C.I.	Adj. OR[b]	95% C.I.	Cases (n)	Non-cases (n)	Crude OR	95% C.I.	Adj. OR[b]	95% C.I.
O_3													
	3	148	772	1.03	[0.81, 1.32]	1.07	[0.82, 1.38]	70	226	1.04	[0.68, 1.58]	1.12	[0.71, 1.79]
	5	245	1,372	1.14	[0.93, 1.41]	1.19	[0.96, 1.47]	120	417	0.86	[0.61, 1.20]	0.80	[0.55, 1.17]
	10	392	2,193	1.16	[0.98, 1.38]	1.13	[0.95, 1.36]	197	711	0.83	[0.63, 1.09]	0.80	[0.59, 1.09]
PM_{10}													
	3	133	668	1.30	[1.06, 1.60]	1.16	[0.94, 1.44]	58	198	1.36	[1.00, 1.84]	1.27	[0.89, 1.82]
	5	212	1,092	1.29	[1.09, 1.52]	1.20	[1.00, 1.43]	97	339	1.13	[0.89, 1.43]	1.00	[0.74, 1.34]
	10	367	2,018	1.17	[1.03, 1.33]	1.08	[0.94, 1.24]	180	662	1.06	[0.86, 1.29]	1.00	[0.78, 1.27]
$PM_{2.5}$													
	3	94	425	1.45	[1.10, 1.91]	1.23	[0.91 ,1.66]	42	131	1.45	[0.92, 2.30]	1.18	[0.69 ,2.00]
	5	160	830	1.36	[1.09, 1.71]	1.22	[0.96, 1.56]	73	262	1.19	[0.84, 1.68]	1.01	[0.69, 1.49]
	10	286	1,547	1.28	[1.08, 1.52]	1.15	[0.96, 1.37]	148	523	1.26	[0.98, 1.61]	1.15	[0.86, 1.54]
NO_2													
	3	122	616	1.74	[1.30, 2.32]	1.52	[1.12, 2.06]	67	187	1.45	[0.93, 2.25]	1.28	[0.80, 2.06]
	5	200	1,115	1.33	[1.06, 1.69]	1.18	[0.92, 1.50]	113	356	1.23	[0.86, 1.75]	1.17	[0.81, 1.69]
	10	331	1,893	1.35	[1.12, 1.64]	1.24	[1.01, 1.51]	185	621	1.27	[0.95, 1.71]	1.20	[0.90, 1.61]

[a]For CHIS 2003 current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same neighborhood for at least 9 months were included.
[b]Adjusted for age, race, poverty level, and sex.

IV. DISCUSSION

In this study, we linked ambient air monitoring and traffic data to California Health Interview Survey data. This study tested the hypotheses: 1) Vulnerable sub-populations in California (e.g., racial/ethnic minorities and low-income individuals) have higher exposures to air pollution; 2) Individuals with asthma exposed to higher levels of air pollution are more likely to report adverse asthma outcomes, such as: asthma attacks or episodes, asthma emergency department (ED) visits, use of daily medication to control asthma, school or work absences, and daily/weekly asthma symptoms. Individuals with asthma-like symptoms (defined here as individuals without physician-diagnosed asthma who reported wheezing) and exposed to higher levels of air pollution are more likely to report: wheezing or whistling sound in the chest, attacks of wheezing or whistling, seeking medical care for such symptoms, and work/school days missed due to such symptoms; 3) Air pollution exposures, low socioeconomic status (SES), and certain "vulnerability factors" associated with low SES, exert independent adverse effects on individuals with asthma or asthma-like symptoms. The vulnerability factors examined were: **co-morbidity** (such as diabetes or heart disease); **access to care** (health insurance status, usual source of care); **disease management/asthma severity** (taking daily medication to control asthma, receiving an asthma management plan); **health behaviors** (being overweight/obese, smoking, walking outdoor, engaging in physical activity); **exposure to indoor triggers** (environmental tobacco smoke and indoor allergens, cockroaches, dogs and cats); and **housing conditions** (single family dwelling or apartment, crowding); and 4) Higher pollutant exposures interact with these vulnerability factors resulting in greater air pollution impacts on asthma in vulnerable sub-populations (racial/ethnic minorities, low-income individuals). The findings supported these hypotheses. The discussions comparing the relevant findings in the literature to the results of the study are detailed in the following sections.

Disparities in Exposure to Air Pollutants among Californians with Asthma

In general, we observed that respondents living below 200% of the federal poverty level (FPL) and minority respondents had higher estimated pollutant exposures and lived nearer to highways or major roadways and in areas of higher traffic density. Adults and children with current asthma living below 200% of the federal poverty level (FPL) had higher annual average exposures to NO_2, PM_{10}, and $PM_{2.5}$ than those living at or above 400% of the FPL. Racial/ethnic minorities, such as Latinos, African Americans and Asian/Pacific Islanders/others had higher $PM_{2.5}$, PM_{10}, and NO_2 exposures than whites; However, white adults and children had higher exposures to ozone than respondents in either of these three minority groups. Mean traffic density measures were higher for both Latino and African American children than for white children.

Our findings of disparities across pollutant and traffic exposures are similar to those reported by previous investigators. Gunier et al. (2003) reported that Californians in the lowest quartile of median family income were more likely to live in high-traffic areas than those in the highest income quartile. Children of color have also been previously shown to be more likely to live in high traffic areas than white children (Gunier, Hertz et al. 2003; Houston, Wu et al. 2004). Green et al. (2004) reported elementary schools in California with high proportions of economically-disadvantaged and non-white children were more likely to be located within proximity to roadways with high traffic counts (Green, Smorodinsky et al. 2004). Other studies in Southern California using air toxics emission inventory data found that transportation sources were the most important sources for lifetime cancer risk, especially for racial minorities (Morello-Frosch, Pastor et al. 2001; Pastor, Morello-Frosch et al. 2005). Limited numbers of studies have used air monitoring data to assess disparities in exposures. A study in Sweden reported inverse relationships between NO_2 exposures at residences and schools and children's economic statuses (Chaix, Gustafsson et al. 2006).

Disparities in air pollution exposures that we and other investigators have observed stem from a long history of social and economic injustice, including racial segregation, housing discrimination, and land-use inequities (Houston, Wu et al. 2004). For instance, Jerrett et al. (2001) reported lower housing values in Hamilton, Canada were strongly associated with higher concentrations of particulate pollution(Jerrett, Burnett et al. 2001). Our observations related to O_3 were also consistent with previous studies. For example, O_3 levels were substantially higher in southern Mexico City, a higher socioeconomic status area, compared to the lower SES northern city (Castillejos, Gold et al. 1995). Similarly, respondents in our study living farther from urban areas, such as in suburbs, had higher levels of annual exposure to O_3. This could be explained by the fact that it takes time for O_3 to form through photochemical reactions. O_3 is usually higher in areas downwind of sources of NOx and VOCs; for example, the highest levels in the LA Basin are in eastern areas/suburbs. O_3 can also be lower in areas closer to heavy traffic due to scavenging by NO from traffic (Godish 1991).

Pollutant Effects on Asthma Outcomes

Among adults, we observed associations between annual average pollutant exposures and several asthma outcomes: frequent asthma symptoms (daily/weekly symptoms), asthma attacks or episodes, use of daily medication to control asthma, school or work absences due to asthma, and asthma ED visits, in the 12 months prior to the CHIS 2003 interview. In line with previous studies, asthma attacks were associated with higher exposures to O_3 among adults in our study (Slaughter, Lumley et al. 2003). Also for adults, ED visits, using daily asthma medication, and missing 2 or more days of work due to asthma were associated with higher exposures to three of the four pollutants in the study (O_3, PM_{10}, $PM_{2.5}$). These findings are consistent with previous literature showing a relationship between ED visits and higher levels of O_3 (Romieu, Meneses et al. 1995; Tolbert, Mulholland et al. 2000; Friedman, Powell et al. 2001), PM_{10} (Meng, Rull et al. 2010) and $PM_{2.5}$ (Norris, YoungPong et al. 1999) and between daily/weekly asthma symptoms and higher exposures to $PM_{2.5}$ in adults (Ward and Ayres 2004; Meng, Rull et al. 2010).

Since much of the literature on the effects of air pollution on asthma has focused on children, our study will help to fill gaps in the literature for adult asthma. Our findings, which show an association between air pollution and missed work days due to asthma, are an important contribution to the literature since to the best of our knowledge there are few previous studies showing this association. As fewer studies have been conducted on asthma medication use and air pollution, our results will support and add to existing studies supporting an association (Thurston, Lippmann et al. 1997; Gent, Triche et al. 2003; Slaughter, Lumley et al. 2003; Gent, Koutrakis et al. 2009).

Associations between NO_2 and asthma outcomes were more clearly seen among children. Among children in our study, daily asthma medication and missing 2 or more days of school/day care were associated with higher exposures to NO_2. This is consistent with prior studies linking NO_2 to asthma medication use in children (Gauderman, Avol et al. 2005; Schildcrout, Sheppard et al. 2006) and missed school days due to asthma (O'Connor, Neas et al. 2008).

With regard to days of exceedance of state or federal standards, we found associations with asthma outcomes in adults and children, primarily for respondents in the highest quartiles of exceedance days. Among adults, exceedances of state O_3 standards were associated with increased odds for asthma attacks, visiting the ED, and using a daily asthma medication. We also found exceedances of the state PM_{10} standard were associated with increased odds of asthma ED visits in adults. Exceedances of the federal $PM_{2.5}$ standard were associated with increased odds of ED visits and daily/weekly asthma symptoms. Among children, O_3 exceedances (state 1-hr standard) were associated with increased odds of missing 2 or more days of school. In previous studies, the number of exceedance days of state or federal standards is often used to examine short-term exposure effects; however our findings add to the existing knowledge that many days of exceedance of the standards may also have chronic effects on individuals with asthma, which confirms the importance of maintaining federal and state standards to protect the respiratory health of California's population.

Based on these latest analyses using CHIS 2003 data, we only observed few consistent positive associations between traffic density and residential proximity to traffic and asthma outcomes among current asthmatics or respondents with asthma-like symptoms. These findings are in contrast to our earlier studies in which we estimated strong positive associations between residential traffic density and asthma symptoms for CHIS 2001 respondents living in Los Angeles and San Diego Counties. For example, in our previous studies we estimated approximately two-fold greater odds of daily or weekly asthma symptoms (OR=2.11; 95% CI=1.38–3.23) in adult respondents with a lifetime asthma diagnosis, comparing individuals in the highest to the lowest quintile of traffic density (Meng, Wilhelm et al. 2007). Similarly, children with a lifetime diagnosis of asthma and in the highest quintile of traffic density were estimated to have 3 times higher odds of ED visits or hospitalizations (OR=3.27, 95% CI=1.08–9.89) than children in the lowest quintile of traffic density (Meng, Wilhelm et al. 2007; Wilhelm, Meng et al. 2008). The discrepancies in results may be due to several factors. First, our CHIS 2001 analyses focused on Los Angeles and San Diego Counties, as those were the two counties where residential cross-street information was collected from respondents. The mean and maximum traffic density values for subjects residing in those two highly urbanized areas were slightly higher than the traffic density values estimated here for respondents throughout the entire state of California. When we isolated our current analyses to LA and SD counties, we still did not observe associations with daily or weekly asthma symptoms in adults. However, we observed a 15% increase in odds of asthma ED visits in adults per interquartile increase in traffic density (OR=1.15, 95% CI=1.03-1.28) and an approximately 2-fold increase in odds of ED visits for those in the highest compared to lowest traffic density exposure quartile (OR=2.34, 95% CI=1.15-4.78). We did not observe associations between traffic density and odds of ED visits in children, even after restricting analyses to LA and SD Counties, but the sample size available was smaller than in our previous CHIS 2001 study, since previously we included all lifetime asthmatics and here we include only current asthmatics. Also, the CHIS 2003 sample is smaller than CHIS 2001 in general (42,000 versus 55,000 households, respectively).

Second, previously we used Highway Performance Monitoring System (HPMS) traffic count data obtained directly from Caltrans to estimate traffic density and did not impute values to un-counted roadway segments. For this study, the Caltrans roadmap with linked HPMS data was no longer available and therefore we used TeleAtlas Dynamap traffic data and imputed values to roadway segments with missing traffic counts. By assigning the median traffic count for a given roadway category to roadway segments within the same roadway category without traffic counts across the entire state, we may have introduced additional error into our traffic density measures. Further investigation is needed to identify a better method for assessing traffic exposures for all Californians.

Pollutant and Asthma Outcome Relationships after Adjusting for Vulnerability Factors

In addition to pollutant exposures, several other characteristics were related to increased odds of asthma outcomes (ED visits, taking a daily asthma medication, or missing 2 or more days of work). Odds of having these asthma outcomes were higher among African Americans and Latinos compared to whites. ED visits were more likely among respondents living below 200% of the FPL compared to those living at or above 400% of the FPL, asthma medication use was more likely among respondents ages 65 or older, and missing 2 or more days of work was more likely among women than men.

Other vulnerability factors, such as having heart disease and having adult onset of asthma, independently increased the odds of ED visits and asthma medication use among adults with current asthma. Also, having health insurance, having a usual source of care, or being a previous or current smoker independently increased the possibility of taking daily medications for asthma. Other factors, such as no secondhand smoking at home decreased the possibility of missing at least 2 days of work due to asthma.

Among children, those living below 200% and between 200-399% of the FPL consistently had higher odds of using daily asthma medication than those living at or above 400% of the FPL. Living in a mobile home increased the odds of using a daily asthma medication.

These findings contribute to the existing literature that, in addition to pollutant exposures, vulnerability factors, such as access to care (Meng, Babey et al. 2006) and other behavioral risk factors such as smoking or secondhand smoking (Silverman, Boudreaux et al. 2003), are independently associated with severe asthma. Our findings were consistent with other studies that suggest that comorbidities, especially cardiovascular disease, may also contribute to increases in negative health outcomes related to asthma (Gouveia and Fletcher 2000; Aga, Samoli et al. 2003; Anderson, Atkinson et al. 2003; Sandstrom, Frew et al. 2003; Filleul, Rondeau et al. 2004; Gauderman, Avol et al. 2004; Meng, Wilhelm et al. 2007).

There are some counterintuitive findings, such as the increased odds of an ED visit for those with an asthma management plan or a daily asthma medication. This may be related to the fact that CHIS is a cross-sectional survey, which introduces temporal ambiguity between outcomes and adjustment variables. In this case, individuals may be more likely to take daily medication or receive a disease management plan after an ED visit. Also, these findings could be due to the fact that these two measures may be indicators of disease severity, which is highly correlated with ED visits. The other counterintuitive findings, such as the presence of cockroaches in the home and experiencing delays in care for any medical reason decreasing the odds of having daily medication or missing 2 or more work days, may be explained by the observation that these respondents were likely to be low-income populations; therefore, they may not have been able to afford medication nor had paid sick days, so they could not afford to miss work.

Pollutant Interactions with Poverty and Race/Ethnicity for Asthma Outcomes

Another major contribution of this study is the detection of significant interactions for poverty and race/ethnicity, indicating that some racial/ethnic and income groups may be more vulnerable to the effects of air pollutant exposures on asthma outcomes. African American and Asian/Pacific Islander adults may be more vulnerable to the effects of NO_2 on respiratory health. Also, minority children appeared to have increased vulnerability to NO_2 and PM_{10}. Specifically, for the same increase in NO_2 exposure, African American and Asian/PI/other adults had greater increases in two or more missed days of work due to asthma compared to white adults. African American adults also had a greater increase in daily/weekly asthma symptoms for a similar increase in NO_2 exposure. American Indian/Alaska Native and Asian/PI/other children had greater increases in daily/weekly symptoms than white children with similar exposure to NO_2. For children we also observed significant interactions between race/ethnicity and PM_{10}, with Latino children having a greater increase in using daily asthma medication for the same increase in PM_{10} levels, and African-American and Asian/PI/other children having greater increases in experiencing daily/weekly symptoms for the same increase in PM_{10} exposure compared to white children. Additionally, we found significant interactions for household poverty level and NO_2 exposure; among children we found a greater increase in odds of ED visits among those living below 200% of the FPL compared to those living at or above 400% of the FPL for the same increase in NO_2 exposure.

As Lipfert (2004) and others have pointed out, low socioeconomic status is a double-edged sword that fosters living in areas of increased pollution and also makes individuals more vulnerable to pollutant effects (Sexton and Adgate 1999; O'Neill, Jerrett et al. 2003; Lipfert 2004). In addition to pollutant exposures, these lower SES groups suffer from the burden of reduced health from material deprivation and psychosocial stress. Although a limited number of studies have addressed whether SES modifies the health effects of air pollution among those in disadvantaged circumstances, some of these studies provide support for our findings. In a study of chronic effects, neighborhood income level modified the health effects of air pollution (Finkelstein, Jerrett et al. 2003). They found that people with low incomes and high exposure were 2.3 times more likely to die from causes associated with air pollution exposures than those in the same exposure groups with high incomes. Our previous study using CHIS 2001 also had similar findings. We found greater estimated traffic effects for asthmatics in poverty, whereas the estimates for asthmatics above the poverty level moved closer toward the null (Meng, Wilhelm et al. 2008). The increased vulnerability of these low SES sub-populations may result from many factors. A lower consumption of anti-oxidants and nutrients to prevent inflammation among these sub-populations may be a contributing factor (Sienra-Monge, Ramirez-Aguilar et al. 2004). Also, low SES groups often live in older housing, which may not be well insulated, and thus have potentially higher intrusion of outdoor pollutants, such as motor vehicle exhaust (Houston, Wu et al. 2004). Additionally, exposures to other indoor allergens, such as dust mites and fungal spores that are believed to induce asthma symptoms (Zhong 1996) are more common in households with low SES status (Sarpong, Hamilton et al. 1996).

Psychosocial stress has been linked to asthma morbidity (Wright and Steinbach 2001; Wright, Mitchell et al. 2004; Clougherty, Levy et al. 2007) and was also found to be higher among lower SES individuals than higher SES individuals with asthma (Chen, Fisher et al. 2003). Our findings contribute to the existing literature since these interactions have not been demonstrated in other studies. However, further studies are needed to better explore these relationships and to determine factors contributing to these differential effects.

Asthma-like Symptoms among Californians

Exposure disparities among respondents with asthma-like symptoms were overall very similar to those found for respondents with current asthma. In general, adults and children living below 400% of the FPL had higher pollutant exposures with some exceptions, notably O_3 for children and adults and PM_{10} for children. Latinos had higher annual average pollutant concentrations for all pollutants except O_3. We observed associations for wheeze and some pollutants, and our results are suggestive of associations between pollutants and two or more wheeze attacks as well as seeking medical help for wheezing. On average, associations for wheeze outcomes and pollutants appeared weaker than those for the asthma outcomes. This may be due to outcome misclassification, since wheezing is a broad outcome that may include people with undiagnosed asthma, viral illnesses, chronic conditions, or other respiratory issues. Respondents who mentioned COPD, emphysema, or bronchitis when asked about wheezing or whistling sounds in their chest in the past year were excluded from the wheeze outcomes, but this was only if they mentioned having one of these conditions. The literature on asthma-like symptoms is sparse. One study found environmental tobacco smoke and low-socioeconomic status to be associated with asthma-like symptoms (Yeatts, Davis et al. 2003).

Study Strengths and Limitations

Currently, California only has surveillance capacity for asthma hospitalizations and ED visits, therefore, only reflecting severe asthma outcomes. CHIS provides a representative sample of Californians and the ability to examine air pollution associations with many other outcome measures among current asthmatics that affect a much larger population than asthma mortality and hospitalizations/ED visits, such as medication use, frequency of symptoms, and school/work days missed while adjusting for many potential confounders. For instance, we had information on many potential confounding risk factors for asthma such as socioeconomic status, asthma disease management, behavior-related factors (e.g., smoking), access to health care, housing conditions and indoor air pollution exposures (e.g., secondhand smoking), and co-morbidities. Thus, this study provided an opportunity to examine the independent, as well as combined, effects of these factors on health outcomes. In addition to asthma outcomes, the study also evaluated associations with the prevalence of asthma-like symptoms among Californians with undiagnosed asthma or other respiratory diseases.

California has a large, ethnically diverse populations and covers geographic areas with both high and low air pollution levels in comparison to the rest of the nation. Therefore, it is very important to address a major goal of CARB's Environmental Justice Policy "to better characterize air pollution exposures in communities and to better assess health impacts, especially non-cancer effects, cumulative effects, and effects from long-term low-level exposures on vulnerable populations." To our knowledge, this is the first study to test the following hypotheses: 1) Vulnerable sub-populations in California (e.g., racial/ethnic minorities and low-income individuals) have higher exposures to air pollution; 2) Individuals with asthma or asthma-like symptoms exposed to higher levels of air pollution are more likely to report adverse health outcomes; 3) Air pollution exposures, low socioeconomic status, and certain vulnerability factors exert independent adverse effects on individuals with asthma or asthma-like symptoms; and 4) Higher pollutant exposures interact with vulnerability factors, resulting in greater air pollution impacts on asthma in vulnerable sub-populations.

Some limitations associated with using CHIS data should be noted. First, this study is based on one year of CHIS survey data (2003) with a limited sample of Californians with asthma or asthma-like symptoms. Therefore, cautions need to be taken when generalizing the findings to the entire state population and to the impact of air pollution over years. Also, CHIS is a cross-sectional survey, which may raise concerns regarding temporal ambiguity between our outcome and pollutant measures. Because the CHIS 2003 survey collected information on duration of residence in the same house and neighborhood, we used 12-month pollutant data prior to the interview date and limited our study sample to those living in the same neighborhood for at least 9 months. Thus, even though we were not able to ascertain whether exposures occurred before outcome events in some cases (e.g. ED visits), we were able to assure that the exposure measurement periods were contemporaneous with the outcome measurement periods. Another limitation to note is that the study outcomes (such as prior asthma diagnosis) were self-reported and not verified by objective clinical measures. While clinical measurements of airway responsiveness appear to reflect the activity and severity of asthma at the time of measurement, it is generally accepted that data on long-term prevalence of symptoms and exacerbations may be better obtained by questionnaires (Eder, Ege et al. 2006).

There may also be concerns regarding selection bias due to non-response. For instance, Californians with low-SES may be less likely to respond to the survey. Selection bias usually occurs when the exposure could systematically influence the selection/response of cases and/or controls. For example, bias may result from a higher or lower response rate in exposed cases than exposed controls. However, we believe that it is unlikely that CHIS respondents were aware of their personal exposure status in order to self-select differentially i.e. that it is most likely both cases and controls were selected independently of their knowledge of exposure status, since exposure status was not determined by interview retrospectively (vulnerable to recall bias), but calculated from routinely collected air monitoring and traffic data. In a subsequent survey (CHIS 2007), CHIS has conducted a special survey procedure in which follow up could be done with persons who were selected for the sample but did not respond to attempts to interview them as part of the telephone survey to try to assess the non-response bias. This survey found relative to the responders, that non-responders were more likely to be younger, Latino, tended to live in households with children, tended to be less educated, and have lower income. When low-SES Californians are the least likely to respond to the survey and also the most likely to be exposed, it will indirectly lead to differential bias by exposure status. Furthermore, people with health problems may also be more or less likely to respond for various reasons. Though selection bias is particularly relevant in case-control studies, even when the design is population-based like CHIS, it could still be an important issue for the reasons mentioned above.

Since most of the questions relevant to the study in CHIS asked respondents to recall what happened in the previous 12 months, there might be recall bias or error in the self-reported asthma morbidity indicators. Errors in recall might lead us to categorize some cases and non-cases improperly. Previous studies have shown that people are able to recall frequent events (such as frequent asthma symptoms) or rare but clinically significant episodes (such as ED visits or being diagnosed with asthma) very well (Pless and Pless 1995). However, this might not be true for certain measures, for instance, respondents might not be able to recall the number of days of school/work missed due to asthma accurately for more than the proximate past. As a result, we decided to use the measure of 2 or more school days missed instead of number of work/school days missed, which may be more error prone. We would expect this error to be similar for exposed and unexposed cases, i.e., non-differential with regard to exposure status.

Since CHIS is a telephone-based survey, the rapid growth of cellular telephone use over the past decade may create coverage problems for CHIS. Cell phones may generate two issues that may lead to non-coverage bias in telephone surveys. To assess non-coverage bias in CHIS, the landline RDD sample was supplemented with a sample of adults living in households with only cell phones in 2007. For the cell-phone-only sample, a sample of telephone numbers designated for cellular use was drawn and screened; only cell phone users that did not have a landline telephone at home were eligible to complete the adult survey. CHIS found relative to the landline sample, the cell-phone-only sample had a slightly higher proportion of non-Latino African Americans and a lower proportion of non-Latino whites than the landline sample. The household income of the cellular phone respondents is lower, perhaps reflecting a higher likelihood of having lower education and being single. The cell-phone-only sample is less likely to be unemployed by 11.7 percentage point. Again, if we believe the patterns of cell-phone-only households applies to CHIS 2003, it will indirectly lead to differential bias by exposure status when low-SES Californians are the least likely to be included in the survey and also the most likely to be exposed.

We mainly relied on residence-based air pollution exposure estimates and therefore lack personal exposure measures. CHIS did not collect information on respondents' work locations. Thus, our exposure measures did not take into account inter-individual variability in exposures due to personal mobility, and indoor, commuting and occupational exposures, and other factors, especially for non-elderly adults. However, previous cohort studies that included multiple communities assigned exposure based on community-average pollution concentrations and considered long-term health effects have shown that the results are relatively unaffected by a lack of personal exposure measures (Berhane K. 2004). We did a sensitivity analysis, as recommended by the Research Screening Committee, to examine the potential importance of the resulting exposure misclassification on our air pollution effect estimates. Based on stratified analyses, we observed that the association between PM_{10} and increased odds of ED visits in adult asthmatics appeared isolated to employed individuals (Table 37), which is the opposite of what one would expect if exposure measures were less misclassified for unemployed individuals and this misclassification is non-differential. Employed individuals could have other risk factors (e.g., co-morbidities) that make them more vulnerable to PM_{10} effects. Or associations in employed individuals may reflect, in part, time spent commuting, since in-vehicle air pollution exposures have been shown to be higher than ambient exposures (Fruin et al., 2004, Westerdahl et al., 2005, Zhu et al., 2007).

People in developed countries tend to spend the majority of their time indoors, and thus exposure to outdoor air pollution is modified by time spent indoors. One important factor influencing indoor and personal exposures to pollutants is the fraction of outdoor air that penetrates indoors, which is a function of pollutant type and home ventilation characteristics, including use of air conditioning. CHIS did not ask questions about the age of housing structures and use of air conditioning. The American Housing Survey (AHS) collected such data for a limited number of metropolitan cities, and we could not link that data to CHIS respondents. We originally planned to use these data to identify certain characteristics of people that have air conditioning (e.g., high SES) so that we could use those characteristics to extrapolate air conditioning use information to the CHIS population for stratified analyses. However, since the use of air conditioning also depends heavily on meteorology and topographic conditions of an area, e.g. residents of coastal areas are less likely to use air conditioning, we decided not to use the AHS data for extrapolating air conditioning use. Indoor pollutant exposures may be elevated in low income housing due to multiple sources, such as cigarette smoking, mold, and gas appliance combustion and small apartment sizes (Zota, Adamkiewicz et al. 2005). For example, levels of NO_2 and CO have been found to be substantially higher in low income, inner-city residences relative to the U.S. average (Schwab 1990). Additionally, exposures to cockroaches, dust mites, and fungal allergens that are believed to induce asthma symptoms (Zhong 1996) are more common in households with generally poor living conditions (Sarpong, Hamilton et al. 1996). In addition to adult and adolescent active smoking habits, CHIS 2003 asked if anyone smokes cigarettes, cigars, or pipes anywhere inside the home, and if yes, about how many days per week. CHIS 2003 also ascertained if any dogs/cats are allowed inside the home and whether any cockroaches were present inside the home in the past 12 months, as well as type of housing. Thus we assessed exposures to these indoor pollutants and controlled for them as potential confounders in our analyses. However, CHIS did not ask questions about all the other possible asthma triggers, such as age of housing, mold, dust mites, and use of gas appliances. As a result, we could not control for these possible triggers in this study.

V. SUMMARY AND CONCLUSIONS

Although several studies have linked air pollution to asthma morbidity, studies are still needed to identify vulnerable sub-populations with a higher burden of asthma and to investigate whether higher pollutant exposures and possibly increased vulnerability to pollutants among these sub-populations contribute to the excess burden. Linking existing air pollutant data from ambient monitors, traffic data, and California Health Interview Survey (CHIS) 2003 data allowed us to conduct a study to address these issues. This study furthers the California Air Resources Board's (CARB) Vulnerable Population Research Program that aims to protect all California residents, particularly individuals considered especially susceptible, from the adverse effects of air pollution.

To investigate the effects of air pollution on those with asthma and asthma-like symptoms in California and to identify potentially vulnerable subgroups, we conducted a cross-sectional study linking California Health Interview Survey (CHIS) 2003 data to existing air pollutant and traffic data. We considered three populations in our analyses, CHIS 2003 respondents with lifetime asthma (N=5,620 adults and 1,889 children), current asthma (N=3,587 adults and 1,224 children), and those not diagnosed with asthma who experienced asthma-like symptoms (N=4,413 adults and 1,109). Respondents living in their current neighborhood for less than nine months were excluded. Using Geographic Information System (GIS) software, we linked these respondents' residential addresses to the nearest government air monitoring stations for each of four criteria pollutants (O_3, PM_{10}, $PM_{2.5}$, and NO_2). We then calculated annual pollutant averages for the 12-month period prior to respondents' interview dates. Additionally, we calculated the number of days concentrations measured at the nearest air monitor exceeded federal and state standards for these pollutants. To capture exposure to traffic pollutants, we assessed traffic density and distance to roadways as proxies for traffic exposure based on residential address. Once the exposures were calculated for respondents, we performed logistic regression analyses on respondents with asthma and respondents with asthma-like symptoms, separately for children and adults. Logistic regressions and interaction terms were used to evaluate increased vulnerability to pollutants among sub-populations. We also conducted pollutant-outcome analyses adjusting for several potential confounders related to vulnerability, such as smoking, obesity, heart disease, and having a usual source of health care.

In conclusion, we observed disparities in exposure to air pollutants by federal poverty level, and race/ethnicity among Californians with current asthma. In general, higher annual average exposures were observed for lower income groups and racial/ethnic minorities for NO_2, PM_{10}, and $PM_{2.5}$. In contrast, annual average O_3 exposure was generally lower or the same in these groups compared to the corresponding reference groups. Similar exposure disparities were observed for respondents with asthma-like symptoms. Among adults, we observed linear increases in odds of having asthma attacks, using daily asthma medication, missing 2 or more work days due to asthma, and asthma-related emergency department visits with increasing annual average pollutant concentrations for O_3, PM_{10}, and $PM_{2.5}$. Among children, use of daily asthma medication and school/day care absences were associated with higher exposures to annual average NO_2 concentration. We also observed associations with the number of days exceeding federal or state standards for O_3, PM_{10}, and $PM_{2.5}$. We observed few consistent associations between residence-based measures of traffic and asthma outcomes in adults. We also were able to adjust for several potential confounders in our analyses and found that pollutant associations remained. Some of the novel findings of this work are the interaction effects for race/ethnicity and household federal poverty level with annual average pollutant exposures for NO_2 and PM_{10}, suggesting that racial/ethnic minority and low-income groups have greater increases in adverse health effects at the same level of increase in exposures. In respondents with undiagnosed asthma, positive associations were observed between asthma-like symptoms and annual air pollutant averages and exceedance measures, and again only a few associations were seen with traffic density and distance roadway measures.

VI. RECOMMENDATIONS

Our results provide much needed information on the effects of long-term air pollution exposure on chronic severe asthma and asthma-like symptoms in uniquely vulnerable populations, such as racial/ethnic minorities, and low-income Californians. The results of this project indicated that current air quality in California needs to be further improved in order to protect sensitive populations, such as those suffering from asthma or asthma like symptoms; also, more actions need to be taken to protect vulnerable sub-populations.

Further regulatory efforts are needed to reduce emissions and identify contributing sources and toxic constituents of air pollution. In addition to regulatory interventions to reduce emissions, interventions at the community level should also be given attention, for example, by requiring minimum distances to pollutant sources, e.g. freeways. Locating schools, day care centers, work places, homes, sports fields and parks away from busy roadways and other emission sources should be part of the requirements for community development. Also, reductions in diesel bus/truck idling and increases in retrofitting and replacement of diesel buses and trucks could also provide important protection for vulnerable populations. Additional monitoring of air pollution from mobile sources, for example near freeways and major roads, would be a tremendous asset in assessing the health effects of traffic related pollution. Individual level interventions are also needed to modify pollutant exposure and/or dose and to help individuals mitigate the health effects of air pollution. For instance, information on control of air pollution exposures, such as reducing outdoor activities when the air quality index is in the unhealthy range and exercising away from major roadways should be widely spread. Our study also indicates that further studies are needed to explore the relationships of socioeconomic status and race with air pollution and respiratory health effects. Other important areas for future work include research identifying factors that may increase vulnerability to pollutant effects and the testing of innovative strategies to reduce individual exposures and vulnerability to air pollution through community-based or family-focused interventions.

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VIII. LIST OF INVENTIONS REPORTED AND COPYRIGHTED MATERIALS PRODUCED

Not applicable.

IX. GLOSSARY OF TERMS, ABBREVIATIONS, AND SYMBOLS

µg- microgram
µm- micrometer
AADT- annual average daily traffic
AI- American Indian
AN- Alaska Native
BMI- body mass index
BRFSS- Behavioral Risk Factor Surveillance System
CARB- California Air Resources Board
CHIS- California Health Interview Survey
CI- confidence interval
CO- carbon monoxide
COPD- Chronic Obstructive Pulmonary Disorder
ED- emergency department
EPA- Environmental Protections Agency
FPL- federal poverty level
ft- feet
GIS- Geographic Information System
HPMS- Highway Performance Monitoring System
hr- hour
km- kilometer
L- length
m- meter
NHIS- National Health Interview Survey
NO_2- nitrogen oxide
NTAD- National Transportation Atlas Database
O_3- ozone
OR- odds ratio
PAR- population attributable risk
PI- Pacific Islander
PM- particulate matter
PM_{10}- particulate matter less than 10 µm in aerodynamic diameter
$PM_{2.5}$- particulate matter less than 2.5 µm in aerodynamic diameter
ppb- parts per billion
RDD- random-digit dial
SES- socioeconomic status
SO_2- sulfur dioxide
std. error- standard error
TD- traffic density
UC- University of California
VMT- Vehicle Meters Traveled

X. APPENDIX

Table 6. Weighted distributions of annual pollutant averages, exceedance days, and traffic density (within 750 feet) for CHIS 2003 adults and children with current asthma[a]

	Adults (≥18 years)								Children (< 18 years)							
	n	Missing	Min	Max	Mean	Std Error of Mean	Median	95th Percentile	n	Missing	Min	Max	Mean	Std Error of Mean	Median	95th Percentile
Pollutant Averages																
O_3 (ppb)	1,617	242	22.8	63.5	41.6	0.27	40.1	54.7	537	62	23.0	64.2	41.3	0.49	39.5	54.4
PM_{10} (µg/m^3)	1,304	224	12.3	80.1	28.6	0.34	27.0	45.2	436	67	13.0	80.1	30.0	0.61	29.6	46.2
$PM_{2.5}$ (µg/m^3)	990	703	4.1	27.5	16.0	0.18	15.4	23.4	335	216	7.4	26.2	16.8	0.34	17.8	23.5
NO_2 (ppb)	1,315	482	1.5	36.1	21.1	0.27	20.0	35.0	469	127	1.6	36.0	22.0	0.48	21.3	35.1
Exceedances (in days)																
O_3 1-Hr (State)	1,621	236	0	122	22.4	0.87	9.8	75.3	540	59	0	122	24.9	1.63	11.7	70.9
O_3 8-Hr (State)	1,617	242	0	153	31.1	1.11	16.0	97.9	537	62	0	153	33.5	2.10	16.7	98.6
O_3 8-Hr (Federal)	1,617	242	0	114	16.8	0.77	4.0	65.1	537	62	0	114	18.4	1.39	4.7	63.8
PM_{10} (State)	1,304	224	0	66	7.2	0.37	2.9	25.6	436	67	0	65	7.8	0.65	3.1	26.7
PM_{10} (Federal)	1,304	224	0	4	0.1	0.02	0.0	0.0	436	67	0	4	0.1	0.02	0.0	0.7
$PM_{2.5}$ (Federal)	990	703	0	54	15.5	0.49	12.8	41.3	335	216	0	54	17.5	0.99	14.2	48.1
Traffic density (VMT/day/meter^2)																
750 feet buffer[b]	2940	1	0.1	583.0	66.0	2.29	47.4	195.2	1018	0	1.1	793.4	70.1	4.06	45.7	284.4

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b]Based on imputed Tele Atlas traffic data.

Table 7. Frequencies for distance to roadway measures for CHIS 2003 adults and children with current asthma[a]

Roadway Measure	Adults (≥18 years) n	Adults (≥18 years) % (Weighted)	Children (< 18 years) n	Children (< 18 years) % (Weighted)
<300 m from a State Highway[b]	134	5.4	45	5.4
<300 m from an Interstate Highway[b]	281	9.9	102	12.1
<50 m from a Major Road[b]	584	20.5	172	19.1
<50 m from a Minor Road[b]	2,546	87.1	894	90.2

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived in the same home or neighborhood for at least 9 months and geocoded based on address and nearest cross-streets were included.
[b]Based on imputed Tele Atlas data.

Table 8. Pearson correlations between annual average air pollutant concentrations, exceedance measures, distance to roadway measures and traffic density[a]

	O_3 (ppb)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	NO_2 (ppb)	Traffic Density (750 ft buffer) (VMT/day/meters^2)	Distance to State Highway (meters)	Distance to Interstate (meters)	Distance to Major Roads (meters)	Distance to Minor Roads (meters)	O_3 1-Hr (State) (days)	O_3 8-Hr (Federal) (days)	O_3 8-Hr (State) (days)	PM_{10} (Federal) (days)	PM_{10} (State) (days)	$PM_{2.5}$ (Federal) (days)
O_3 (ppb)	1														
PM_{10} (µg/m^3)	0.49	1													
$PM_{2.5}$ (µg/m^3)	0.39	0.78	1												
NO_2 (ppb)	0.04	0.56	0.72	1											
Traffic Density (750 ft buffer) (VMT/day/meters^2)[b]	-0.06	0.03	0.05	0.13	1										
Distance to State Highway (meters)[b]	0.21	-0.02	-0.10	-0.18	0.06	1									
Distance to Interstate (meters)[b]	0.14	-0.02	-0.12	-0.18	-0.26	-0.01	1								
Distance to Major Roads (meters)[b]	0.05	0.01	-0.06	-0.06	-0.22	-0.05	0.22	1							
Distance to Minor Roads (meters)[b]	0.00	-0.04	-0.04	-0.05	0.01	0.04	0.14	-0.04	1						
O_3 1-Hr (State) (days)	0.82	0.59	0.49	0.25	-0.01	0.22	0.06	0.02	0.01	1					
O_3 8-Hr (Federal) (days)	0.83	0.56	0.45	0.13	-0.03	0.23	0.10	0.03	0.01	0.98	1				
O_3 8-Hr (State) (days)	0.89	0.56	0.43	0.12	-0.05	0.23	0.13	0.04	0.01	0.95	0.97	1			
PM_{10} (Federal) (days)	0.19	0.43	0.06	-0.02	-0.04	-0.04	0.10	0.05	-0.01	0.15	0.16	0.15	1		
PM_{10} (State) (days)	0.44	0.81	0.49	0.22	-0.02	0.02	0.03	0.03	-0.02	0.56	0.56	0.54	0.60	1	
$PM_{2.5}$ (Federal) (days)	0.15	0.51	0.69	0.45	0.05	-0.05	-0.11	-0.09	-0.07	0.20	0.17	0.19	-0.04	0.32	1

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station, lived in the same home or neighborhood for at least 9 months, and geocoded by address or nearest cross streets were included.
[b]Based on imputed Tele Atlas traffic data.

Table 10. Characteristics of CHIS 2003 children and adults with current asthma[a]

		Adults			Children		
		n	Pop. N	% (wtd.)	n	Pop. N	% (wtd.)
Sex							
	Male	960	591,941	34.7	658	491,096	58.4
	Female	2,383	1,115,836	65.3	495	350,513	41.6
Age (yr)							
	0-5	-	-	-	222	177,434	21.1
	6-11	-	-	-	469	315,611	37.5
	12-17	-	-	-	462	348,564	41.4
	18-34	664	491,308	28.8	-	-	-
	35-64	1,964	939,448	55.0	-	-	-
	65+	715	277,021	16.2	-	-	-
Race/Ethnicity							
	Latino	368	294,678	17.3	245	226,661	26.9
	American Indian/Alaska Native	73	34,409	2.0	31	24,224	2.9
	Asian/Other	286	205,060	12.0	139	101,540	12.1
	African American	282	143,060	8.4	125	122,906	14.6
	White	2,334	1,030,571	60.3	613	366,277	43.5
Education[b]							
	Less than 25 Years of Age	225	194,646	11.4	-	-	-
	High School Education or Less	1,035	585,913	34.3	404	322,053	38.3
	College or Vocational School	1,604	734,275	43.0	595	421,236	50.1
	Graduate School	479	192,942	11.3	154	98,319	11.7
Work Status							
	Employed	1,945	1,051,873	61.8	-	-	-
	Unemployed	1,385	649,135	38.2	-	-	-
Federal Poverty Level							
	0-199%	1,041	555,437	32.5	365	323,103	38.4
	200-399%	837	407,082	23.8	376	259,102	30.8
	≥400%	1,465	745,258	43.6	412	259,404	30.8
Insurance Status							
	Uninsured All/Part of the Year	393	274,915	16.1	71	41,168	4.9
	Insured All of the Year	2,950	1,432,862	83.9	1,082	800,440	95.1
Usual Source of Care							
	Yes	3,108	1,541,916	90.3	1,061	761,728	90.5
	No	235	165,861	9.7	92	79,881	9.5
Delay in Needed Care in Last 12 Months							
	Yes	723	359,191	21.0	101	68,460	8.1
	No	2,620	1,348,586	79.0	1,052	773,148	91.9
Number of Doctor Visits in the Past Year							
	0-1	587	345,241	22.1	251	181,385	22.9
	2-5	1,361	708,038	45.4	664	481,506	60.8
	6+	1,088	506,905	32.5	173	128,836	16.3
Age at Asthma Diagnosis							
	0-11	985	578,871	33.9	1,050	761,521	90.5
	12-17	309	186,378	10.9	103	80,087	9.5
	18-64	1,824	850,537	49.8	-	-	-
	65+	225	91,991	5.4	-	-	-
Daily Asthma Medication							
	Yes	1,653	813,586	47.6	421	311,250	37.0
	No	1,690	894,190	52.4	732	530,358	63.0
Asthma Management Plan							
	Yes	1,326	642,716	37.6	527	342,473	40.7
	No	2,017	1,065,060	62.4	626	499,136	59.3

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, “Do you still have asthma?"; only those who lived in the same home or neighborhood for at least 9 months were included.

[b] Representative of educational attainment level of the adult respondent or adult responding on behalf of the child.

Table 10: Characteristics of CHIS 2003 children and adults with current asthma[a] (continued)

	Adults			Children		
	n	Pop. N	% (wtd.)	n	Pop. N	% (wtd.)
Self-reported Health Status						
Good/Very Good/Excellent	2,258	1,147,937	67.2	969	683,856	81.3
Poor/Fair	1,085	559,840	32.8	184	157,753	18.7
Heart Disease (Adults)						
Yes	477	193,285	11.3	-	-	-
No	2,866	1,514,491	88.7	-	-	-
Congestive Heart Failure (Adult)						
Yes	96	26,817	31.7	-	-	-
No	132	57,865	68.3	-	-	-
Diabetes						
Yes	324	162,681	9.5	-	-	-
No	2,979	1,528,892	89.5	-	-	-
Borderline	40	16,204	1.0	-	-	-
Body Mass Index (Adult)						
Underweight/Normal	1,267	654,162	38.3	-	-	-
Overweight/Obese	2,076	1,053,615	61.7	-	-	-
Body Mass Index (Teen)						
Underweight/Normal	-	-	-	290	221,431	63.5
Overweight/Obese	-	-	-	172	127,133	36.5
Smoking Status (Adult)						
Current/Previous Smoker	1,625	773,413	45.5	-	-	-
Never Smoker	1,705	927,596	54.5	-	-	-
Smokers in the Home						
Yes	358	190,362	11.1	69	64,252	7.6
No	2,985	1,517,415	88.9	1,084	777,356	92.4
Walking for Transportation or Leisure						
Yes	2,291	1,192,768	71.1	-	-	-
No	976	484,724	28.9	-	-	-
Dogs/Cats in the Home						
Yes	1,669	815,216	47.7	533	344,173	40.9
No	1,674	892,560	52.3	620	497,436	59.1
Cockroaches in the Home						
Yes	324	209,029	12.2	156	130,013	15.4
No	3,019	1,498,748	87.8	997	711,596	84.6
Rural/Urban						
Urban	1,208	682,214	39.9	402	342,472	40.7
2nd City	956	470,474	27.5	384	235,309	28.0
Suburban	549	338,098	19.8	200	176,753	21.0
Town/Rural	630	216,991	12.7	167	87,075	10.3
Time at Current Address/Neighborhood						
9 months-<1 yr	47	29,301	1.7	21	15,668	1.9
1-<3 yr	529	313,186	18.3	232	181,218	21.5
3+ yr	2,767	1,365,290	79.9	900	644,722	76.6
Housing Type						
House	2,237	1,138,493	66.7	877	597,592	71.0
Apartment, Duplex, or Mobile Home	1,106	569,284	33.3	276	244,017	29.0
Household Crowding (CHIS 2003)						
Yes	319	277,822	16.3	279	280,846	33.4
No	3,024	1,429,955	83.7	874	560,762	66.6

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only those who lived in the same home or neighborhood for at least 9 months were included.

[b]Representative of educational attainment level of the adult respondent or adult responding on behalf of the child.

Table 11 (Detailed). Disparities in weighted mean annual pollutant concentrations by various demographic characteristics in CHIS 2003 children and adults with current asthma using bivariate analysis[a]

		NO_2 annual average (ppb)		O_3 annual average (ppb)		PM_{10} annual average (μg/m^3)		$PM_{2.5}$ annual average (μg/m^3)	
		Adult	Child	Adult	Child	Adult	Child	Adult	Child
Demographics		mean	mean	mean	mean	mean	mean	mean	mean
Household Federal Poverty Level	0 - 199 % FPL	22.4***	24.1***	41.1	41.0	29.9**	30.6*	16.7***	17.5**
	200 - 399 % FPL	20.7	20.6	42.1	42.0	28.1	31.3**	16.4**	16.9*
	≥ 400%†	20.1	20.2	41.8	41.1	27.8	28.0	15.0	15.3
Race/ethnicity	Latino	24.2***	23.9***	41.1*	40.6*	31.3***	30.8	17.9***	17.2*
	Alaskan Native / American Indian	19.2	23.9	42.0	47.0	29.4	32.1	15.3	19.3
	Asian / Pacific Islander / Other	22.6***	23.8**	40.4*	38.1***	28.8	28.8	16.2	16.6
	African American	21.0	22.1*	39.3***	40.0*	29.3	31.7	16.2*	17.8*
	White†	19.6	19.7	42.5	43.1	27.6	29.1	15.1	15.7
Urban/Rural	Urban†	24.4	25.1	38.9	37.8	28.6	29.3	16.2	17.0
	Second City	17.4***	18.7***	42.8***	44.3***	28.2	28.8	15.1**	15.6
	Suburban	20.1***	19.6***	44.6***	45.5***	30.2*	33.7**	17.1	17.9
	Town/ Rural	10.6***	13.7***	47.6***	43.5**	27.7	28.6	10.8***	13.9***
Sex	Male	20.8	22.6	41.2	41.4	27.7*	30.9	15.7	17.4*
	Female	21.2	21.1	41.9	41.2	29.1	28.9	16.2	15.9
Age (in years)	0-5		22.7		41.9		31.5		17.8
	6-11		22.3		40.7		29.6		16.5
	12-17†		21.2		41.6		29.8		16.6
	18-34	22.0*		41.4		29.6*		16.5	
	35 - 64	21.0		41.8		28.3		15.8	
	65 and above†	19.9		41.6		27.8		15.6	

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.

†Reference Group

*p < 0.05, **p < 0.01, ***p < 0.001

Table 12. Disparities in traffic and distance to roadways by various demographic characteristics in CHIS 2003 children and adults with current asthma using bivariate analysis[a]

		Teleatlas Traffic Density Within 750-ft Buffer (VMT/day/meter^2)[b]		State Highway < 300 m[b]		Interstate Highway < 300 m[b]		Major Road < 50 m[b]	
		Adult	Child	Adult	Child	Adult	Child	Adult	Child
Demographics		mean	mean	%	%	%	%	%	%
Household Federal Poverty Level	0 - 199 % FPL	66.6	84.6***	7.0	9.5*	9.2	16.4**	26.4***	24.7*
	200 - 399 % FPL	68.6	70.2*	5.2	3.3	11.0	12.8	23.7 *	20.7
	≥400% FPL†	64.1	52.7	4.3	2.6	9.8	6.3	17.5	15.3
Race/Ethnicity	Latino	67.0	93.6***	6.3	€	7.5	18.1*	24.2	19.9
	Alaskan Native / American Indian	58.6	93.0	€	€	€	€	27.1	€
	Asian / Pacific Islander / Other	88.9	54.3	€	€	12.2	€	19.5	17.3
	African American	76.6*	89.8**	€	€	13.6	€	22.8	26.0
	White†	60.2	53.2	4.7	4.1	9.8	8.5	21.3	19.8
Urban/Rural	Urban†	80.6	84.6	4.4	4.7	10.9	11.3	22.9	27.1
	2nd City	59.4***	57.4**	4.5	4.8	8.9	9.0	22.5	14.2**
	Suburban	59.5**	68.8	4.1	2.8	10.3	18.0	17.3	18.1
	Town/Rural	40.6***	46.4***	13.3***	14.1	6.9*	10.8	24.0	15.6*
Sex	Male	65.3	68.3	3.3**	5.3	9.0	12.1	23.0	18.6
	Female†	66.4	72.7	6.5	5.4	10.4	12.0	21.2	23.3
Age	0-5		74.1		6.9		13.4		15.5
	6-11		73.1		6.9		14.9		22.4
	12-17†		65.7		3.3		8.9		21.5
	18-34	64.4		7.2		8.9		22.4	
	35 - 64	65.8		4.2		10.0		22.6	
	65 and above†	69.1		6.7		11.3		18.1	

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same neighborhood for at least 9 months were included.

[b]Based on imputed Tele Atlas data.

†Reference Group

€ Unstable values (CV > 30%)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13. Disparities in weighted prevalence of asthma outcomes by various demographic characteristics in CHIS 2003 children and adults with current asthma using bivariate analysis[a]

		Asthma Attack[b]		ED Visits		Daily Asthma Medication		Missed ≥2 days of work/school[c]		Daily/weekly asthma symptoms	
		Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children
Demographics		%	%	%	%	%	%	%	%	%	%
Household Federal Poverty Level	0 - 199 % FPL	40.3***	32.1*	24.1 ***	26.4**	53.8***	45.7***	14.6	54.3***	35.0***	12.9
	200 - 399 % FPL	32.6	37.1	12.8	23.0*	46.4	34.4	13.9	47.12*	31.0*	12.9
	≥400% FPL †	32.9	40.4	12.6	14.7	43.7	28.7	11.8	33.2	25.2	9.0
Race/ethnicity	Latino	32.6	29.8*	26.8***	25.5	44.5	45.4**	21.9***	54.1	22.2**	11.5
	Alaskan Native / American Indian	47.4	38.0	€	€	56.2	€	€	€	34.0	€
	Asian / Pacific Islander / Other	36.8	36.8	18.0	€	41.0	32.5	16.7*	35.0	25.2*	12.8
	African American	34.3	44.2	19.3	32.3*	59.4**	37.6	19.7**	48.8	30.2	-
	White †	35.0	37.9	12.7	18.8	48.0	31.5	8.8	42.7	32.7	11.6
Urban/Rural	Urban †	33.5	35.0	17.0	25.0	45.8	39.6	15.6	45.1	27.7	10.4
	Second City	34.8	36.3	15.9	19.6	51.6	37.5	11.3*	49.1	31.5	15.4
	Suburban	36.5	37.5	16.5	24.2	46.1	35.8	13.2	49.3	28.1	8.9
	Town and Rural	38.0	36.8	15.2	9.7***	47.5	27.7*	9.6*	29.2*	35.3*	12.6
Sex	Male	25.9***	36.6	13.8 *	23.7	45.4	35.9	10.3*	47.2	26.1*	10.9
	Female †	41.8	35.3	17.8	19.0	48.8	38.5	14.7	43.4	31.7	12.8
Age	0-5		55.2***		44.3***		37.7		51.2		
	6-11		41.1***		26.7***		38.1		42.9		8.9*
	12-17 †		23.4		5.8		35.7		-		16.1
	18-34	29.7		13.9		35.2***		13.9		20.3***	
	35 - 64	38.5		18.7*		48.4***		13.8		32.3*	
	65 and above †	33.9		13.1		67.3		€		38.1	

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only those who lived in the same home or neighborhood for at least 9 months were included.
[b]Respondents ever diagnosed with asthma who lived in the same home or neighborhood for at least 9 months were included.
[c]Data not collected for teen respondents
†Reference Group
€ Unstable values (CV > 30%)
*p < 0.05, **p < 0.01, ***p < 0.001

Table 14 (Detailed). Associations (OR (95% CI)) for 12-month pollutant averages and respiratory outcomes in CHIS 2003 adults and children with current asthma[a]

	Asthma Attack[b]						ED Visit for Asthma						Daily Asthma Medication					
Pollutant	Cases	Non-Cases	Crude OR	95% C.I.	Adj. OR[d]	95% C.I.	Cases	Non-Cases	Crude OR	95% C.I.	Adj. OR[d]	95% C.I.	Cases	Non-Cases	Crude OR	95% C.I.	Adj. OR[d]	95% C.I.
Adults																		
O_3 (per 10 ppb)	965	1582	1.20	[1.06, 1.36]	**1.20**	[1.05, 1.36]	245	1372	1.14	[0.93, 1.41]	1.19	[0.96, 1.47]	815	802	1.21	[1.03, 1.41]	**1.22**	[1.04, 1.43]
PM_{10} (per 10 μg/m^3)	770	1272	1.07	[0.94, 1.21]	1.04	[0.92, 1.18]	212	1092	1.29	[1.09, 1.52]	**1.20**	[1.00, 1.43]	659	645	1.10	[0.95, 1.28]	1.12	[0.96, 1.30]
$PM_{2.5}$ (per 5 μg/m^3)	592	974	1.09	[0.95, 1.27]	1.07	[0.93, 1.24]	160	830	1.36	[1.09, 1.71]	1.22	[0.96, 1.56]	494	496	1.19	[1.00, 1.42]	**1.26**	[1.05, 1.52]
NO_2 (per 10 ppb)	782	1313	1.01	[0.87, 1.18]	0.99	[0.84, 1.15]	200	1115	1.33	[1.06, 1.69]	1.18	[0.92, 1.50]	667	648	1.01	[0.85, 1.21]	1.08	[0.90, 1.30]
Children																		
O_3 (per 10 ppb)	315	515	0.91	[0.72, 1.14]	0.88	[0.69, 1.12]	120	417	0.86	[0.61, 1.20]	0.80	[0.55, 1.17]	192	345	0.87	[0.65, 1.15]	0.88	[0.66, 1.17]
PM_{10} (per 10 μg/m^3)	245	430	0.97	[0.79, 1.19]	0.97	[0.77, 1.22]	97	339	1.13	[0.89, 1.43]	1.00	[0.74, 1.34]	154	282	1.04	[0.81, 1.33]	0.97	[0.75, 1.26]
$PM_{2.5}$ (per 5 μg/m^3)	196	318	0.99	[0.76, 1.28]	0.96	[0.74, 1.26]	73	262	1.19	[0.84, 1.68]	1.01	[0.69, 1.49]	132	203	1.29	[0.94, 1.78]	1.20	[0.87, 1.65]
NO_2 (per 10 ppb)	282	430	0.93	[0.72, 1.19]	0.97	[0.74, 1.27]	113	356	1.23	[0.86, 1.75]	1.17	[0.81, 1.69]	171	298	1.46	[1.07, 2.00]	1.36	[0.99, 1.87]

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same neighborhood for at least 9 months were included.

[b]Respondents ever diagnosed with asthma who lived within 5 miles of an air monitoring station and in the same home or neighborhood for at least 9 months were included.

[c]Adjusted for age, race, poverty level, and sex.

[d]Data not collected for teen respondents.

Table 14 (Detailed). Associations (OR (95% CI)) for 12-month pollutant averages and respiratory outcomes in CHIS 2003 adults and children with current asthma[a] (continued)

	Missed ≥2 School/Work Days Due to Asthma[c]						Daily/Weekly Asthma Symptoms					
Pollutant	Cases	Non-Cases	Crude OR	95% C.I.	Adj. OR[d]	95% C.I.	Cases	Non-Cases	Crude OR	95% C.I.	Adj. OR[d]	95% C.I.
Adults												
O_3 (per 10 ppb)	176	1208	1.09	[0.88, 1.37]	1.15	[0.91, 1.46]	504	1113	1.06	[0.90, 1.25]	1.03	[0.87, 1.22]
PM_{10} (per 10 μg/m^3)	142	977	1.36	[1.08, 1.72]	**1.28**	[1.00, 1.65]	415	889	1.00	[0.86, 1.17]	1.03	[0.89, 1.20]
$PM_{2.5}$ (per 5 μg/m^3)	118	743	1.34	[1.03, 1.74]	1.23	[0.94, 1.60]	316	674	1.07	[0.89, 1.28]	1.15	[0.96, 1.39]
NO_2 (per 10 ppb)	147	985	1.41	[1.07, 1.86]	1.24	[0.93, 1.65]	410	905	0.96	[0.80, 1.16]	1.03	[0.85, 1.25]
Children												
O_3 (per 10 ppb)	152	184	1.22	[0.87, 1.71]	1.18	[0.83, 1.68]	60	477	0.84	[0.51, 1.37]	0.77	[0.48, 1.21]
PM_{10} (per 10 μg/m^3)	121	139	1.16	[0.83, 1.62]	1.07	[0.77, 1.49]	50	386	0.93	[0.67, 1.29]	0.89	[0.63, 1.25]
$PM_{2.5}$ (per 5 μg/m^3)	96	109	1.25	[0.88, 1.79]	1.17	[0.80, 1.70]	44	291	1.45	[0.91, 2.30]	1.32	[0.85, 2.05]
NO_2 (per 10 ppb)	132	166	1.40	[0.98, 1.98]	1.35	[0.94, 1.96]	51	418	1.17	[0.73, 1.87]	1.13	[0.72, 1.75]

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same neighborhood for at least 9 months were included.

[b]Respondents ever diagnosed with asthma who lived within 5 miles of an air monitoring station and in the same home or neighborhood for at least 9 months were included.

[c]Data not collected for teen respondents.

[d]Adjusted for age, race, poverty level, and sex.

Table 15. Associations (OR (95% CI)) between air pollution exceedance days and asthma outcomes in CHIS 2003 adults and children with current asthma[a]

	Asthma Attack[b]				ED visit for asthma				Daily Asthma Medication				Missed ≥2 school/work days due to asthma[c]				Daily/weekly asthma symptoms			
Exceedances in days	Cases	Non-Cases	OR[d]	95% C.I.	Cases	Non-Cases	OR[d]	95% C.I.	Cases	Non-Cases	OR[d]	95% C.I.	Cases	Non-Cases	OR[d]	95% C.I.	Cases	Non-Cases	OR[d]	95% C.I.
Adults																				
O_3 1-Hr (State) - Ref: < 0.8 days																				
0.8 days - < 8.7 days	271	470	1.11	[0.82, 1.51]	67	400	1.10	[0.64, 1.89]	222	245	0.86	[0.59, 1.25]	53	354	1.26	[0.67, 2.35]	128	339	0.56	[0.38, 0.82]
8.7 days - < 36.7 days	257	413	1.35	[0.98, 1.84]	63	370	1.27	[0.75, 2.16]	216	217	1.17	[0.80, 1.70]	45	325	1.65	[0.89, 3.06]	134	299	0.80	[0.54, 1.19]
≥ 36.7 days	256	376	**1.40**	[1.03, 1.91]	76	318	**1.91**	[1.14, 3.18]	217	177	**1.52**	[1.03, 2.24]	52	281	1.59	[0.87, 2.92]	135	259	0.96	[0.65, 1.42]
O_3 8-Hr (State) - Ref: < 1.9 days																				
1.9 days - < 14.3 days	260	425	1.19	[0.89, 1.61]	56	383	0.79	[0.46, 1.36]	212	227	0.90	[0.63, 1.31]	43	338	0.88	[0.47, 1.64]	122	317	0.55	[0.38, 0.81]
14.3 days - <51.2 days	222	392	1.19	[0.87, 1.62]	57	325	1.07	[0.64, 1.78]	195	187	1.18	[0.81, 1.71]	47	282	1.30	[0.73, 2.31]	120	262	0.79	[0.54, 1.17]
≥ 51.2 days	285	402	**1.44**	[1.07, 1.94]	82	355	1.42	[0.88, 2.28]	238	199	**1.50**	[1.04, 2.18]	50	319	1.24	[0.70, 2.20]	145	292	0.87	[0.59, 1.27]
PM_{10} (State) - Ref: < 1.6 days																				
1.6 days - < 3.5 days	193	300	1.29	[0.92, 1.80]	49	276	1.50	[0.86, 2.60]	160	165	0.83	[0.56, 1.23]	32	245	1.02	[0.52, 2.00]	97	228	0.71	[0.47, 1.09]
3.5 days - < 6.6 days	140	230	1.25	[0.86, 1.79]	43	189	1.58	[0.89, 2.79]	106	126	0.93	[0.62, 1.39]	27	181	1.74	[0.89, 3.40]	70	162	1.03	[0.66, 1.61]
≥ 6.6 days	223	347	1.19	[0.86, 1.66]	74	289	**1.77**	[1.05, 2.97]	197	166	1.16	[0.79, 1.72]	50	262	1.70	[0.91, 3.18]	118	245	0.95	[0.63, 1.43]
$PM_{2.5}$ (Federal) - Ref: 4.8 days																				
4.8 days - < 12.0 days	105	201	0.75	[0.50, 1.12]	24	169	0.88	[0.43, 1.78]	103	90	1.11	[0.70, 1.79]	11	147	0.31	[0.12, 0.80]	61	132	1.20	[0.73, 1.97]
12.0 days - < 23.9 days	205	294	1.08	[0.75, 1.55]	58	268	1.22	[0.67, 2.22]	155	171	0.95	[0.61, 1.46]	40	248	0.90	[0.46, 1.75]	96	230	1.02	[0.66, 1.59]
≥ 23.9 days	133	222	1.06	[0.72, 1.56]	46	168	**2.01**	[1.10, 3.68]	114	100	1.49	[0.92, 2.39]	37	148	1.69	[0.85, 3.35]	76	138	**1.66**	[1.02, 2.68]
Children																				
O_3 1-Hr (State) - Ref: < 0.8 days																				
0.8 days - < 8.7 days	89	150	0.64	[0.33, 1.25]	40	116	1.85	[0.74, 4.61]	55	101	0.62	[0.31, 1.26]	47	50	**2.73**	[1.09, 6.84]	14	142	0.87	[0.31, 2.44]
8.7 days - < 36.7 days	90	143	0.68	[0.35, 1.34]	35	112	1.48	[0.56, 3.88]	49	98	0.70	[0.34, 1.43]	40	50	1.98	[0.78, 5.02]	19	128	0.68	[0.25, 1.86]
≥ 36.7 days	80	143	0.73	[0.37, 1.43]	30	113	1.09	[0.41, 2.90]	55	88	0.87	[0.43, 1.78]	45	50	**3.00**	[1.20, 7.51]	15	128	0.65	[0.23, 1.79]
O_3 8-Hr (State) - Ref: < 1.9 days																				
1.9 days - < 14.3 days	84	134	0.95	[0.53, 1.69]	33	118	0.76	[0.36, 1.60]	57	94	0.86	[0.44, 1.70]	42	48	1.97	[0.85, 4.59]	14	137	0.48	[0.18, 1.32]
14.3 days - <51.2 days	76	134	0.56	[0.31, 1.02]	27	103	0.67	[0.30, 1.49]	46	84	0.83	[0.40, 1.71]	40	43	1.97	[0.81, 4.81]	15	115	0.45	[0.17, 1.25]
≥ 51.2 days	87	152	0.86	[0.48, 1.54]	34	116	0.66	[0.30, 1.47]	54	96	0.93	[0.48, 1.80]	43	54	1.89	[0.81, 4.43]	19	131	0.63	[0.25, 1.57]
PM_{10} (State) - Ref: < 1.6 days																				
1.6 days - < 3.5 days	53	108	0.68	[0.36, 1.31]	18	86	1.12	[0.44, 2.85]	38	66	1.01	[0.49, 2.11]	28	35	1.10	[0.42, 2.89]	9	95	1.50	[0.56, 4.06]
3.5 days - < 6.6 days	50	85	0.77	[0.41, 1.46]	22	66	1.71	[0.72, 4.07]	32	56	0.96	[0.45, 2.05]	23	30	1.13	[0.43, 3.00]	10	78	1.01	[0.36, 2.79]
≥ 6.6 days	79	140	0.79	[0.43, 1.46]	35	99	1.08	[0.44, 2.64]	51	83	0.82	[0.41, 1.66]	43	39	1.61	[0.64, 4.03]	19	115	1.41	[0.55, 3.61]
$PM_{2.5}$ (Federal) - Ref: 4.8 days																				
4.8 days - < 12.0 days	31	51	1.01	[0.45, 2.29]	12	39	0.46	[0.14,1.54]	16	35	0.72	[0.27, 1.92]	14	19	0.53	[0.16, 1.78]	2	49	0.49	[0.09, 2.62]
12.0 days - < 23.9 days	63	99	0.97	[0.48, 1.93]	19	81	0.78	[0.30, 2.05]	49	51	2.09	[0.93, 4.68]	24	37	0.45	[0.17, 1.17]	16	84	1.68	[0.58, 4.86]
≥ 23.9 days	55	82	0.94	[0.47, 1.89]	25	70	0.92	[0.38, 2.23]	38	57	1.35	[0.61, 2.99]	28	31	0.81	[0.32, 2.08]	14	81	1.11	[0.41, 2.97]

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included. The categories represent the distribution of days over the exceedance measured across quartiles.

[b]Respondents ever diagnosed with asthma who lived within 5 miles of an air monitoring station and in the same home or neighborhood for at least 9 months were included.

[c]Data not collected for teen respondents.

[d]Adjusted for age, race, poverty level, and sex.

Table 16. Associations (OR (95% CI)) for traffic density/distance to roadway and asthma outcomes in CHIS 2003 adults and children with current asthma[a]

	Asthma Attack[b]				ED Visit for Asthma				Daily Asthma Medication				Missed ≥2 School/Work Days Due to Asthma[c]				Daily/Weekly Asthma Symptoms			
Exposure	Cases	Non-Cases	OR[d]	95% C.I.	Cases	Non-Cases	OR[d]	95% C.I.	Cases	Non-Cases	OR[d]	95% C.I.	Cases	Non-Cases	OR[d]	95% C.I.	Cases	Non-Cases	OR[d]	95% C.I.
Adults																				
Tele Atlas Traffic < 750ft Continuous	1,733	2,858	1.03	[0.97,1.09]	438	2,502	1.08	[0.97,1.21]	1455	1,485	1.02	[0.95,1.09]	294	2,205	1.05	[0.95,1.16]	929	2,011	1.00	[0.93,1.07]
Tele Atlas Traffic < 750ft (25th < 50th percentile)[e,f]	437	736	1.05	[0.84, 1.33]	91	640	0.89	[0.59, 1.36]	352	379	0.92	[0.69, 1.22]	70	547	1.19	[0.74, 1.92]	227	504	1.05	[0.78, 1.42]
Tele Atlas Traffic < 750ft (50th < 75th percentile)[e,f]	433	686	1.08	[0.86, 1.37]	120	618	**1.48**	[1.02, 2.16]	359	379	0.98	[0.74, 1.31]	77	549	1.24	[0.77, 1.98]	238	500	1.06	[0.79, 1.43]
Tele Atlas Traffic < 750ft (≥75th percentile)[e,f]	408	653	1.07	[0.84, 1.35]	111	571	1.05	[0.70, 1.58]	350	332	0.89	[0.66, 1.19]	71	510	0.91	[0.58, 1.45]	219	463	0.99	[0.74, 1.34]
State Highway < 300 m[f]	83	132	0.82	[0.55, 1.23]	25	109	0.77	[0.42, 1.41]	73	61	0.91	[0.55, 1.52]	12	102	0.73	[0.32, 1.66]	96	185	1.16	[0.80, 1.68]
Interstate Highway < 300 m[f]	172	248	1.06	[0.79, 1.43]	54	227	1.51	[0.91, 2.48]	159	122	1.34	[0.95, 1.90]	30	209	1.10	[0.64, 1.91]	195	425	0.89	[0.67, 1.17]
Major Road < 50 m[f]	369	563	1.10	[0.90, 1.35]	97	523	1.02	[0.69, 1.50]	308	312	0.96	[0.75, 1.24]	57	486	0.66	[0.44, 0.99]	832	1,830	0.82	[0.55, 1.24]
Children																				
Tele Atlas Traffic < 750ft Continuous	589	990	1.03	[0.93,1.14]	203	815	0.98	[0.88,1.09]	372	646	1.04	[0.94,1.16]	258	347	1.08	[0.94,1.24]	112	906	0.93	[0.76,1.15]
Tele Atlas Traffic < 750ft (25th < 50th percentile)[e,f]	159	273	0.95	[0.62, 1.45]	59	202	0.97	[0.50,1.87]	104	157	1.17	[0.69, 1.97]	72	94	1.37	[0.72, 2.60]	34	227	0.93	[0.42, 2.04]
Tele Atlas Traffic < 750ft (50th < 75th percentile)[e,f]	140	246	0.91	[0.60, 1.40]	46	200	0.93	[0.48,1.81]	93	153	1.58	[0.94, 2.66]	60	80	1.23	[0.63, 2.43]	22	224	0.94	[0.42, 2.12]
Tele Atlas Traffic < 750ft (≥75th percentile)[e,f]	130	208	0.92	[0.59, 1.44]	51	175	0.92	[0.49,1.73]	88	138	1.43	[0.83, 2.47]	71	77	1.59	[0.84, 3.02]	24	202	0.93	[0.38, 2.30]
State Highway < 300 m[f]	26	45	0.76	[0.36, 1.60]	9	36	0.73	[0.19, 2.74]	16	29	0.45	[0.17, 1.22]	11	17	0.80	[0.27, 2.34]	No cases			
Interstate Highway < 300 m[f]	63	88	1.18	[0.67, 2.07]	25	77	1.13	[0.54, 2.37]	39	63	0.79	[0.42, 1.50]	28	39	1.23	[0.60, 2.52]	9	93	0.87	[0.32, 2.37]
Major Road < 50 m[f]	100	190	0.98	[0.67, 1.42]	34	150	0.95	[0.55, 1.62]	68	116	1.24	[0.78, 1.97]	50	57	1.34	[0.77, 2.33]	15	169	0.73	[0.33, 1.61]

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b]Respondents ever diagnosed with asthma who lived within 5 miles of an air monitoring station and in the same home or neighborhood for at least 9 months were included.
[c]Data not collected for teen respondents.
[d]Adjusted for age, race, poverty level, and sex
[e]Reference: < 25^{th} percentile; Units: vehicles per meter/day/$meter^2$
[f]Based on imputed Tele Atlas data.

Table 17 (Detailed). Associations between ED visits and pollutants (O_3, PM_{10}, and $PM_{2.5}$) adjusting for vulnerability characteristics among CHIS adults with current asthma[a]

		O_3 (per 10 ppb)									PM_{10} (per 10 μg/m^3)									$PM_{2.5}$ (per 5 μg/m^3)								
		Model 1 (245, 1372)[b]			Model 2 (245, 1365)[b]			Model 3 (240, 1337)[b]			Model 1 (212, 1092)[b]			Model 2 (212, 1085)[b]			Model 3 (209, 1058)[b]			Model 1 (160, 830)[b]			Model 2 (160, 825)[b]			Model 3 (157, 807)[b]		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average		1.19	0.96	1.47	1.18	0.95	1.47	1.15	0.91	1.45	1.20	1.00	1.43	1.18	0.99	1.42	1.25	1.03	1.51	1.22	0.96	1.56	1.21	0.95	1.54	1.20	0.92	1.56
Age (Ref. ≥65)																												
	18 - 34	1.09	0.61	1.93	1.49	0.78	2.85	2.05	1.00	4.20	1.00	0.53	1.88	1.44	0.72	2.90	1.91	0.88	4.16	0.94	0.45	1.93	1.66	0.76	3.63	1.31	0.57	2.99
	35 - 64	1.91	1.15	3.20	2.26	1.30	3.94	2.33	1.29	4.19	1.76	0.99	3.13	2.19	1.20	4.00	2.29	1.19	4.41	1.64	0.86	3.15	2.20	1.13	4.26	1.88	0.94	3.76
Race (Ref. White)																												
	African American	1.86	1.04	3.32	1.76	0.97	3.20	1.40	0.73	2.68	1.42	0.74	2.71	1.30	0.67	2.53	1.16	0.58	2.29	1.92	0.99	3.71	1.95	0.98	3.87	1.38	0.71	2.67
	AI/AN	1.51	0.43	5.29	1.46	0.42	5.16	0.96	0.29	3.16	1.36	0.38	4.93	1.27	0.33	4.88	0.83	0.24	2.91	0.97	0.16	5.95	0.89	0.14	5.58	0.59	0.10	3.34
	Asian / PI / Other	1.26	0.71	2.26	1.38	0.77	2.47	1.41	0.79	2.51	0.80	0.42	1.54	0.84	0.44	1.59	0.90	0.45	1.79	0.96	0.47	1.96	1.08	0.52	2.23	0.92	0.46	1.84
	Latino	2.03	1.27	3.23	2.08	1.30	3.35	2.23	1.32	3.78	2.42	1.46	4.00	2.46	1.47	4.12	2.40	1.37	4.22	2.03	1.18	3.49	2.38	1.35	4.22	2.05	1.09	3.88
Poverty (Ref. ≥400%)																												
	0 - 199% FPL	1.93	1.26	2.97	1.62	1.02	2.57	1.82	1.12	2.95	2.02	1.27	3.20	1.72	1.06	2.80	1.95	1.15	3.31	1.84	1.11	3.03	1.51	0.90	2.54	1.64	0.93	2.90
	200 - 399% FPL	1.14	0.69	1.89	1.07	0.64	1.80	1.11	0.68	1.83	1.34	0.79	2.27	1.31	0.76	2.25	1.37	0.79	2.39	1.09	0.57	2.06	1.09	0.58	2.05	0.98	0.51	1.90
Sex																												
	Female vs. Male	1.45	0.97	2.18	1.46	0.97	2.21	1.37	0.89	2.10	1.28	0.83	1.97	1.23	0.80	1.88	1.25	0.80	1.96	1.45	0.89	2.37	1.50	0.91	2.45	1.51	0.89	2.55
Currently Insured																												
	Yes vs No				0.95	0.57	1.57							1.06	0.60	1.89							1.31	0.68	2.52			
Obese																												
	No vs Yes				0.80	0.55	1.15							0.70	0.47	1.03							0.83	0.53	1.30			
Heart Disease																												
	Yes vs No				1.69	1.01	2.84							2.07	1.22	3.52							2.12	1.20	3.73			
Smoker																												
	Ever vs Never				1.26	0.87	1.81							0.94	0.64	1.38							1.47	0.93	2.32			
Work Status																												
	Employed vs. Unemployed				0.81	0.54	1.21							0.76	0.50	1.17							0.67	0.41	1.11			
Urban/Rural (Ref. Town/ Rural)																												
	Urban							0.84	0.41	1.70							0.72	0.36	1.46							0.84	0.20	3.53
	Second City							0.98	0.49	1.96							0.72	0.36	1.41							1.06	0.27	4.19
	Suburban							0.83	0.39	1.74							0.62	0.29	1.32							0.71	0.16	3.11
Usual Source of Care																												
	Yes vs No							0.95	0.50	1.79							0.98	0.48	1.99							0.72	0.33	1.56
Delay in Care																												
	Yes vs No							1.30	0.85	1.99							1.32	0.83	2.12							0.94	0.54	1.64
Onset of Asthma																												
	Adult vs Child							1.65	1.08	2.54							1.50	0.94	2.39							1.28	0.78	2.09
Daily Asthma Medication																												
	No vs Yes							0.35	0.23	0.52							0.30	0.20	0.47							0.29	0.17	0.49
Asthma Management Plan																												
	No vs Yes							0.52	0.36	0.76							0.56	0.37	0.84							0.63	0.40	1.00
Household Smoking																												
	No vs Yes							0.85	0.46	1.55							1.28	0.66	2.46							1.10	0.54	2.27
Dog or Cat in Home																												
	No vs Yes							1.01	0.67	1.50							1.01	0.66	1.57							1.18	0.72	1.93
Cockroaches																												
	Yes vs No							0.89	0.50	1.60							0.99	0.53	1.85							0.90	0.47	1.73
Housing Type (Ref. House)																												
	Duplex or Apartment							0.77	0.37	1.61							0.94	0.46	1.96							0.82	0.30	2.24
	Mobile Home							0.58	0.28	1.19							0.80	0.41	1.59							0.62	0.23	1.65
Household Crowding																												
	No vs Yes							1.16	0.68	2.00							1.11	0.60	2.04							1.20	0.63	2.27
Diabetes (Ref. Pre-Diabetes/ Borderline Diabetes)																												
	Yes							1.72	0.18	16.51							1.32	0.14	12.48							0.81	0.08	8.32
	No							0.87	0.10	7.88							0.63	0.07	5.61							0.45	0.05	4.19
Walking																												
	Yes vs No							0.75	0.51	1.11							0.87	0.57	1.34							0.99	0.61	1.61

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b](Cases, Non-cases)

Table 18 (Detailed). Associations between daily asthma medication and pollutants (O_3, PM_{10}, and $PM_{2.5}$) adjusting for vulnerability characteristics among CHIS adults with current asthma[a]

		O_3 (per 10 ppb)									PM_{10} (per 10 $\mu g/m^3$)									$PM_{2.5}$ (per 5 $\mu g/m^3$)								
		Model 1 (815, 802)[b]			Model 2 (811, 799)[b]			Model 3 (789, 788)[b]			Model 1 (659, 645)[b]			Model 2 (654, 643)[b]			Model 3 (634, 633)[b]			Model 1 (494, 496)[b]			Model 2 (491, 494)[b]			Model 3 (479, 485)[b]		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average		1.22	1.04	1.43	1.23	1.05	1.46	1.24	1.05	1.48	1.12	0.96	1.30	1.12	0.96	1.30	1.23	1.04	1.45	1.26	1.05	1.52	1.30	1.07	1.57	1.44	1.18	1.76
Age (Ref. ≥65)																												
	18 - 34	0.32	0.21	0.48	0.52	0.33	0.83	0.30	0.19	0.48	0.32	0.20	0.51	0.51	0.30	0.87	0.33	0.19	0.55	0.40	0.24	0.66	0.80	0.44	1.44	0.41	0.23	0.73
	35 - 64	0.55	0.39	0.78	0.76	0.52	1.12	0.51	0.35	0.74	0.53	0.36	0.79	0.72	0.46	1.13	0.50	0.32	0.77	0.56	0.36	0.88	0.91	0.55	1.49	0.52	0.32	0.85
Race (Ref. White)																												
	African American	1.49	0.92	2.41	1.54	0.95	2.49	1.52	0.92	2.51	1.85	1.07	3.19	1.98	1.15	3.41	2.16	1.22	3.84	1.62	0.92	2.84	1.87	1.05	3.32	1.76	0.97	3.18
	AI/AN	1.88	0.74	4.75	1.89	0.77	4.66	1.77	0.74	4.24	2.46	0.92	6.62	2.56	0.97	6.77	2.47	1.02	5.99	1.85	0.55	6.29	1.85	0.57	6.00	1.84	0.59	5.73
	Asian / PI / Other	0.75	0.47	1.20	0.86	0.54	1.38	0.71	0.44	1.16	0.72	0.41	1.26	0.81	0.46	1.42	0.86	0.48	1.53	0.77	0.45	1.31	0.84	0.49	1.42	0.87	0.50	1.52
	Latino	0.81	0.54	1.20	0.90	0.59	1.36	0.90	0.58	1.39	1.06	0.66	1.68	1.17	0.72	1.90	1.33	0.80	2.21	0.65	0.40	1.06	0.79	0.48	1.29	0.78	0.45	1.36
Poverty (Ref. ≥400%)																												
	0 - 199% FPL	1.30	0.94	1.79	1.16	0.82	1.65	1.41	0.98	2.03	1.16	0.81	1.65	1.06	0.72	1.57	1.28	0.86	1.90	1.28	0.86	1.91	1.12	0.73	1.72	1.45	0.94	2.22
	200 - 399% FPL	0.96	0.68	1.36	0.96	0.68	1.36	0.96	0.68	1.36	0.92	0.62	1.35	0.94	0.63	1.38	0.93	0.62	1.38	0.85	0.55	1.30	0.87	0.56	1.34	0.89	0.57	1.37
Sex																												
	Female vs. Male	1.12	0.85	1.48	1.11	0.84	1.48	1.09	0.82	1.47	0.95	0.69	1.30	0.98	0.71	1.35	0.94	0.67	1.31	1.06	0.75	1.51	1.07	0.75	1.53	0.98	0.68	1.41
Currently Insured																												
	Yes vs No				1.56	1.02	2.38							1.42	0.86	2.35							1.86	1.11	3.11			
Obese																												
	No vs Yes				0.89	0.65	1.21							1.01	0.71	1.45							1.00	0.70	1.44			
Heart Disease																												
	Yes vs No				1.77	1.16	2.69							1.81	1.12	2.91							1.73	1.05	2.84			
Smoker																												
	Ever vs Never				1.41	1.07	1.86							1.31	0.97	1.77							1.47	1.04	2.06			
Work Status																												
	Employed vs. Unemployed				0.75	0.55	1.02							0.78	0.55	1.12							0.58	0.39	0.86			
Urban/Rural (Ref. Town and Rural)																												
	Urban							0.95	0.56	1.60							0.79	0.45	1.38							1.24	0.44	3.50
	Second City							1.25	0.74	2.11							1.07	0.61	1.86							1.91	0.67	5.42
	Suburban							0.82	0.47	1.45							0.70	0.37	1.31							0.90	0.30	2.66
Usual Source of Care																												
	Yes vs No							2.28	1.35	3.85							1.83	1.02	3.28							3.07	1.57	5.99
Delay in Care																												
	Yes vs No							0.76	0.55	1.05							0.68	0.47	0.97							1.03	0.68	1.56
Onset of Asthma																												
	Adult vs Child							1.11	0.83	1.48							1.15	0.83	1.59							1.31	0.92	1.88
Asthma Management Plan																												
	No vs Yes							0.46	0.35	0.61							0.44	0.32	0.60							0.41	0.29	0.59
Household Smoking																												
	No vs Yes							0.84	0.54	1.31							0.76	0.47	1.22							0.65	0.38	1.12
Dog or Cat in Home																												
	No vs Yes							0.89	0.67	1.19							0.73	0.52	1.01							0.80	0.56	1.14
Cockroaches																												
	Yes vs No							0.58	0.38	0.88							0.54	0.33	0.87							0.59	0.36	0.97
Housing Type (Ref. House)																												
	Duplex or Apartment							1.28	0.70	2.34							1.43	0.78	2.65							1.40	0.62	3.20
	Mobile Home							1.19	0.67	2.12							1.26	0.70	2.25							1.33	0.60	2.99
Household Crowding																												
	No vs Yes							0.67	0.43	1.05							0.88	0.52	1.48							0.89	0.53	1.51
Diabetes (Ref. Pre-Diabetes/ Borderline Diabetes)																												
	Yes							0.20	0.05	0.85							0.35	0.06	1.93							0.46	0.08	2.56
	No							0.21	0.05	0.83							0.41	0.08	2.11							0.47	0.09	2.40
Walking																												
	Yes vs No							0.96	0.71	1.29							0.80	0.58	1.11							0.84	0.59	1.20

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.

[b](Cases, Non-cases)

Table 19 (Detailed). Associations between missing 2 or more days of work pollutants (O_3, PM_{10}, and $PM_{2.5}$) adjusting for vulnerability characteristics among CHIS adults with current asthma[a]

		O_3 (per 10 ppb)									PM_{10} (per 10 µg/m^3)									$PM_{2.5}$ (per 5 µg/m^3)								
		Model 1 (176, 1208)[b]			Model 2 (176, 1208)[b]			Model 3 (175, 1185)[b]			Model 1 (142, 977)[b]			Model 2 (142, 977)[b]			Model 3 (141, 957)[b]			Model 1 (118, 743)[b]			Model 2 (118, 743)[b]			Model 3 (118, 727)[b]		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average		1.15	0.91	1.46	1.15	0.91	1.44	1.13	0.88	1.44	1.28	1.00	1.65	1.30	1.01	1.68	1.25	0.96	1.63	1.23	0.94	1.60	1.23	0.94	1.60	1.24	0.93	1.66
Age (Ref. ≥65)																												
	18 - 34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	35 - 64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Race (Ref. White)																												
	African American	3.79	2.02	7.13	3.61	1.92	6.79	3.81	1.82	7.99	3.60	1.73	7.47	3.45	1.69	7.05	3.25	1.43	7.42	4.69	2.24	9.81	4.45	2.11	9.41	5.50	2.35	12.89
	AI/AN	1.73	0.51	5.85	1.62	0.46	5.79	1.86	0.52	6.71	1.83	0.55	6.08	1.67	0.45	6.16	1.93	0.57	6.52	1.13	0.18	7.28	1.01	0.15	6.86	1.34	0.21	8.53
	Asian / PI / Other	2.06	1.07	3.97	1.98	1.01	3.87	2.18	1.11	4.30	1.15	0.49	2.68	1.05	0.46	2.42	1.14	0.47	2.78	1.74	0.82	3.70	1.69	0.78	3.64	1.92	0.91	4.05
	Latino	3.42	2.06	5.68	3.30	1.99	5.49	3.86	2.25	6.64	3.60	2.00	6.47	3.51	1.94	6.36	3.82	2.03	7.18	3.28	1.76	6.10	3.31	1.76	6.23	4.21	2.12	8.33
Poverty (Ref. ≥400%)																												
	0 - 199% FPL	0.57	0.34	0.93	0.59	0.34	1.04	0.45	0.24	0.87	0.58	0.33	1.02	0.67	0.36	1.23	0.54	0.27	1.08	0.37	0.21	0.67	0.39	0.21	0.74	0.36	0.16	0.78
	200 - 399% FPL	1.13	0.67	1.89	1.16	0.69	1.96	1.25	0.75	2.10	1.30	0.73	2.32	1.47	0.82	2.63	1.53	0.85	2.76	0.92	0.50	1.70	1.00	0.53	1.90	1.17	0.64	2.15
Sex																												
	Female vs. Male	2.26	1.39	3.68	2.14	1.31	3.51	2.05	1.24	3.40	2.14	1.25	3.65	1.99	1.16	3.40	2.13	1.20	3.80	2.23	1.24	4.03	2.11	1.15	3.88	2.18	1.18	4.03
Currently Insured																												
	Yes vs No				1.28	0.70	2.35							1.70	0.83	3.50							1.55	0.70	3.45			
Obese																												
	No vs Yes				0.82	0.53	1.27							0.91	0.56	1.49							0.81	0.47	1.39			
Heart Disease																												
	Yes vs No				0.82	0.40	1.69							0.78	0.34	1.78							0.92	0.41	2.06			
Smoker																												
	Ever vs Never				0.76	0.49	1.20							0.64	0.39	1.05							0.81	0.47	1.40			
Urban/Rural (Ref. Town and Rural)																												
	Urban							0.68	0.28	1.68							0.50	0.19	1.36							0.25	0.05	1.29
	Second City							0.59	0.24	1.46							0.48	0.18	1.30							0.26	0.05	1.33
	Suburban							0.59	0.22	1.57							0.52	0.17	1.58							0.21	0.04	1.17
Usual Source of Care																												
	Yes vs No							1.54	0.71	3.34							2.05	0.76	5.53							1.76	0.72	4.33
Delay in Care																												
	Yes vs No							0.89	0.56	1.41							0.71	0.41	1.22							0.47	0.25	0.89
Onset of Asthma																												
	Adult vs Child							0.77	0.48	1.22							0.75	0.45	1.25							0.72	0.43	1.20
Daily Asthma Medication																												
	No vs Yes							0.44	0.28	0.69							0.44	0.26	0.74							0.49	0.28	0.86
Asthma Management Plan																												
	No vs Yes							0.76	0.50	1.15							0.89	0.56	1.43							0.97	0.59	1.59
Household Smoking																												
	No vs Yes							0.48	0.25	0.94							0.55	0.26	1.15							0.50	0.23	1.10
Dog or Cat in Home																												
	No vs Yes							0.97	0.59	1.60							1.19	0.69	2.06							0.69	0.38	1.23
Cockroaches																												
	Yes vs No							2.10	1.16	3.79							1.46	0.76	2.82							1.46	0.73	2.91
Housing Type (Ref. House)																												
	Duplex or Apartment							0.48	0.19	1.25							0.77	0.23	2.63							1.64	0.37	7.29
	Mobile Home							0.45	0.18	1.14							0.65	0.21	2.08							1.26	0.29	5.39
Household Crowding																												
	No vs Yes							0.96	0.52	1.76							0.98	0.49	1.96							1.05	0.53	2.09
Diabetes (Ref. Pre-Diabetes/ Borderline Diabetes)																												
	Yes							-	-	-							1.02	0.06	16.36							0.88	0.06	12.12
	No							-	-	-							1.58	0.11	21.85							1.13	0.10	13.04
Walking																												
	Yes vs No							1.08	0.68	1.72							1.18	0.69	2.00							1.11	0.60	2.06

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b](Cases, Non-cases)

Table 20 (Detailed). Associations between daily asthma medication and $PM_{2.5}$ adjusting for vulnerability characteristics among CHIS 2003 children with current asthma[a]

		$PM_{2.5}$ (per 5 µg/m^3) (132, 203)[b]								
		Model 1			Model 2			Model 3		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Pollutant Average		1.20	0.88	1.63	1.20	0.87	1.64	1.28	0.93	1.76
Age (Ref. 6-11)										
	≤ 6	0.89	0.40	1.99	0.89	0.40	1.99	1.04	0.46	2.36
	12 - 17	1.07	0.56	2.07	1.07	0.55	2.09	1.51	0.74	3.12
Race (Ref. White)										
	African American	1.16	0.46	2.92	1.15	0.43	3.07	1.03	0.40	2.71
	AI/AN	1.11	0.15	8.44	1.11	0.14	8.82	0.84	0.11	6.26
	Asian / PI / Other	0.92	0.34	2.49	0.97	0.36	2.60	0.86	0.32	2.29
	Latino	1.43	0.66	3.10	1.49	0.68	3.26	1.31	0.57	3.00
Poverty (Ref. ≥400%)										
	0 - 199% FPL	2.64	1.22	5.72	2.51	1.14	5.56	3.21	1.40	7.39
	200 - 399% FPL	3.00	1.46	6.14	2.86	1.40	5.87	3.56	1.66	7.60
Sex										
	Female vs. Male	0.96	0.52	1.75	0.96	0.52	1.76	0.92	0.51	1.69
Household Smoking										
	No vs Yes				0.70	0.21	2.30			
Dog or Cat in Home										
	No vs Yes				1.03	0.53	1.99			
Cockroaches										
	No vs Yes				1.01	0.48	2.15			
Currently Insured										
	Yes vs No				0.79	0.24	2.60			
Urban/Rural (Ref. Town and Rural)										
	Urban							0.44	0.08	2.38
	Second City							0.59	0.11	3.12
	Suburban							0.23	0.04	1.30
Delay in Care										
	Yes vs No							1.99	0.65	6.04
Asthma Management Plan										
	No vs Yes							0.38	0.19	0.75
Housing Type (Ref. Mobile Home)										
	Duplex or Apartment							9.75	0.94	101.42
	Mobile Home							11.88	1.20	117.91
Household Crowding										
	No vs Yes							1.13	0.57	2.26

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b](Cases, Non-cases)

Table 24. Interaction effect (OR (95% CI)) of 12-month NO_2 pollutant exposure with poverty or race on asthma outcomes among CHIS 2003 adults and children with current asthma[a]

Interaction		ED Visits (Children)			Missed ≥ 2 Work Days (Adults)			Daily/Weekly Symptoms (Adults)			Daily/Weekly Symptoms (Children)		
		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
NO_2 (10 ppb) by Household FPL													
	0-199% FPL	2.14	1.22	3.74									
	200-399% FPL	0.77	0.41	1.45									
	≥400% FPL†	0.66	0.33	1.34									
NO_2 (10 ppb) by Race													
	Latino				1.20	0.72	2.03	0.63	0.38	1.03	1.18	0.57	2.45
	Alaskan Native / American Indian				1.13	0.23	5.53	0.33	0.07	1.52	-	-	-
	Asian / Pacific Islander / Other				2.72	1.32	5.61	1.32	0.74	2.38	4.52	0.57	35.52
	African American				1.86	0.87	3.96	2.21	1.13	4.33	0.95	0.27	3.37
	White†				0.73	0.47	1.12	1.02	0.81	1.29	0.44	0.21	0.93

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
†Reference group

Table 25. Interaction effect (OR (95% CI)) of 12-month PM_{10} pollutant exposure with race on asthma outcomes among CHIS 2003 children with current asthma[a]

Interaction		Daily Asthma Medication			Daily/Weekly Symptoms		
		OR	95% C.I.		OR	95% C.I.	
PM_{10} (10 $\mu g/m^3$) by Race							
	Latino	1.33	0.87	2.04	0.51	0.25	1.03
	Alaskan Native / American Indian	0.43	0.12	1.50	0.98	0.49	1.94
	Asian / Pacific Islander / Other	0.36	0.16	0.80	2.07	0.93	4.60
	African American	1.40	0.54	3.63	2.48	0.89	6.91
	White†	0.74	0.51	1.08	0.70	0.41	1.17

[a]For CHIS 2003, current asthma is defined as reporting an asthma attack in the previous 12 months or answering yes to the question, "Do you still have asthma?"; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
†Reference group

Table 26. Weighted distributions of annual pollutant averages, exceedance days, and traffic density (within 750 feet) for CHIS 2003 adults and children with asthma-like symptoms[a]

	Adults								Children							
	n	Missing	Min	Max	Mean	Std Error	Median	95th Percentile	n	Missing	Min	Max	Mean	Std Error	Median	95th Percentile
Pollutant Averages																
O_3 (ppb)	2044	298	22.9	65.7	41.7	0.25	40.1	55.0	441	52	22.9	63.5	42.0	0.56	39.7	55.7
PM_{10} ($\mu g/m^3$)	1614	285	7.9	82.8	30.1	0.34	29.2	47.7	348	54	12.8	82.8	29.9	0.72	28.9	45.1
$PM_{2.5}$ ($\mu g/m^3$)	1253	862	4.1	26.9	16.5	0.17	17.0	23.4	274	167	6.6	26.2	16.5	0.36	16.9	23.4
NO_2 (ppb)	1687	616	1.4	36.1	22.0	0.22	21.4	34.9	364	107	5.0	36.0	22.3	0.50	21.3	35.0
Exceedance (in days)																
O_3 1-Hr (State)	2,045	290	0.0	131.0	23.6	0.84	10.3	77.3	442	50	0.0	122.0	24.6	1.82	11.3	76.7
O_3 8-Hr (Federal)	2,044	298	0.0	130.0	17.7	0.73	4.3	64.5	441	52	0.0	114.0	18.5	1.64	4.6	65.9
O_3 8-Hr (State)	2,044	298	0.0	160.0	32.1	1.05	16.7	97.7	441	52	0.0	153.0	33.9	2.40	17.2	99.6
PM_{10} (Federal)	1,614	285	0.0	4.0	0.1	0.02	0.0	0.6	348	54	0.0	4.0	0.1	0.04	0.0	0.8
PM_{10} (State)	1,614	285	0.0	66.0	8.2	0.44	3.2	26.8	348	54	0.0	64.0	7.9	0.99	3.8	26.2
$PM_{2.5}$ (Federal)	1,253	862	0.0	53.6	16.1	0.45	13.6	45.0	274	167	0.0	53.6	16.6	1.23	11.9	46.1
Traffic Density (VMT/day/meter^2)																
750 feet buffer[b]	3,624	5	1.0	745.3	65.8	1.81	45.6	216.2	831	2	0.5	637.2	64.1	3.96	43.4	226.1

[a]For CHIS 2003, having asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b]Based on imputed Tele Atlas traffic data.

Table 27. Frequencies for distance to roadway measures for CHIS 2003 adults and children with asthma-like symptoms[a]

	Adults (≥18 years)		Children (< 18 years)	
Roadway Measure[b]	n	% (Weighted)	n	% (Weighted)
<300 m from a State Highway	189	6.1	46	5.3
<300 m from an Interstate Highway	344	10.4	81	10.8
<50 m from a Major Road	717	19.7	150	17.8
<50 m from a Minor Road	3,253	89.8	752	90.7

[a]For CHIS 2003, having asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived in the same home or neighborhood for at least 9 months, and geocoded by address or nearest cross streets were included
[b]Based on imputed Tele Atlas traffic data

Table 28. Correlations between annual average air pollutant concentrations, exceedance measures, distance to roadways and traffic density[a]

	O_3 (ppb)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	NO_2 (ppb)	Traffic Density (750 ft buffer) (VMT/day/meters^2)	Distance to State Highway (meters)	Distance to Interstate Highway (meters)	Distance to Major Roads (meters)	Distance to Minor Roads (meters)	O_3 1-Hr (State) (days)	O_3 8-Hr (Federal) (days)	O_3 8-Hr (State) (days)	PM_{10} (Federal) (days)	PM_{10} (State) (days)	$PM_{2.5}$ (Federal) (days)
O_3 (ppb)	1														
PM_{10} ($\mu g/m^3$)	0.48	1													
$PM_{2.5}$ ($\mu g/m^3$)	0.34	0.74	1												
NO_2 (ppb)	-0.02	0.50	0.71	1											
Traffic Density (750 ft buffer) (VMT/day/meters^2)[b]	-0.11	0.00	0.00	0.05	1										
Distance to State Highway(meters)[b]	0.20	0.01	-0.08	-0.13	-0.01	1									
Distance to Interstate (meters)[b]	0.22	0.03	-0.09	-0.21	-0.25	0.02	1								
Distance to Major Roads (meters)[b]	0.18	-0.01	-0.09	-0.09	-0.16	-0.05	0.19	1							
Distance to Minor Roads (meters)[b]	0.07	-0.01	0.01	-0.05	-0.01	-0.02	0.17	-0.02	1						
O_3 1-Hr (State) (days)	0.82	0.57	0.44	0.21	-0.10	0.22	0.14	0.10	0.08	1					
O_3 8-Hr (Federal) (days)	0.83	0.54	0.39	0.09	-0.11	0.21	0.19	0.11	0.08	0.98	1				
O_3 8-Hr (State) (days)	0.88	0.55	0.39	0.08	-0.12	0.22	0.23	0.13	0.08	0.95	0.97	1			
PM_{10} (Federal) (days)	0.20	0.45	0.08	0.00	-0.02	-0.03	0.11	0.01	-0.02	0.17	0.17	0.16	1		
PM_{10} (State) (days)	0.45	0.83	0.48	0.20	-0.04	0.04	0.08	0.00	0.00	0.57	0.57	0.55	0.64	1	
$PM_{2.5}$ (Federal) (days)	0.15	0.46	0.71	0.47	0.04	-0.02	-0.09	-0.10	-0.02	0.17	0.13	0.15	-0.03	0.27	1

[a]For CHIS 2003, having asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived within 5 miles of an air monitoring station, lived in the same home or neighborhood for at least 9 months, and geocoded by address or nearest cross streets were included.
[b]Based on imputed Tele Atlas traffic data.

Table 30. Characteristics of CHIS 2003 children and adults with asthma-like symptoms[a]

		Adults			Children		
		n	Pop. N	% (wtd.)	n	Pop. N	% (wtd.)
Sex							
	Male	1,815	1,201,580	50.5	501	382,240	54.9
	Female	2,314	1,176,605	49.5	450	314,279	45.1
Age (yr)							
	0-5	-	-	-	388	286,760	41.2
	6-11	-	-	-	280	198,531	28.5
	12-17	-	-	-	283	211,229	30.3
	18-34	781	672,761	28.3	-	-	-
	35-64	2,502	1,340,825	56.4	-	-	-
	65+	846	364,599	15.3	-	-	-
Race/Ethnicity							
	Latino	615	547,086	23.0	270	238,571	34.3
	American Indian/Alaska Native	98	54,492	2.3	14	7,356	1.1
	Asian/Other	346	225,489	9.5	111	102,324	14.7
	African American	264	160,225	6.7	64	51,602	7.4
	White	2,806	1,390,893	58.5	492	296,666	42.6
Education[b]							
	<25 years old	263	244,568	10.3			
	High School Education or Less	1,614	1,030,693	43.3	381	297,992	42.8
	College or Vocational School	1,803	897,931	37.8	447	322,239	46.3
	Graduate School	449	204,993	8.6	123	76,289	11.0
Work Status							
	Employed	2,570	1,587,771	67.5	-	-	-
	Unemployed	1,530	764,934	32.5	-	-	-
Federal Poverty Level							
	0-199%	1,420	926,384	39.0	344	295,620	42.4
	200-399%	1,072	587,447	24.7	242	164,372	23.6
	≥400%	1,637	864,354	36.4	365	236,527	34.0
Insurance Status							
	Uninsured All/Part of the Year	777	582,943	24.5	79	70,052	10.1
	Insured All of the Year	3,352	1,795,242	75.5	872	626,468	89.9
Usual Source of Care							
	Yes	3,611	1,993,423	83.8	871	622,911	89.4
	No	518	384,761	16.2	80	73,608	10.6
Delay in Needed Care in Last 12 Months (CHIS 2003)							
	Yes	1,060	612,860	25.8	125	85,653	12.3
	No	3,069	1,765,325	74.2	826	610,866	87.7
Number of Doctor Visits in the Past Year							
	0-1	1,161	759,972	33.8	209	161,582	25.0
	2-5	1,633	939,624	41.8	542	388,566	60.0
	6+	1,054	550,124	24.5	140	97,062	15.0
Self-reported Health Status							
	Good/Very Good/Excellent	2,753	1,525,954	64.2	845	602,278	86.5
	Poor/Fair	1,376	852,231	35.8	106	94,241	13.5
Heart Disease (Adults)							
	Yes	571	268,072	11.3	-	-	-
	No	3,558	2,110,113	88.7	-	-	-

[a]For CHIS 2003, having asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived in the same home or neighborhood for at least 9 months were included.
[b]Representative of educational attainment level of the adult respondent or adult responding on behalf of the child.

Table 30. Characteristics of CHIS 2003 children and adults with asthma-like symptoms[a] (continued)

		Adults			Children		
		n	Pop. N	% (wtd.)	n	Pop. N	% (wtd.)
Congestive Heart Failure (Adult)							
	Yes	112	53,894	41.3	-	-	-
	No	181	76,690	58.7	-	-	-
Diabetes							
	Yes	346	182,636	7.7	-	-	-
	No	3,717	2,156,359	90.7	-	-	-
	Borderline	66	39,189	1.7	-	-	-
Body Mass Index (Adult)							
	Underweight/Normal	1,534	891,647	37.5	-	-	-
	Overweight/Obese	2,595	1,486,538	62.5	-	-	-
Body Mass Index (Teen)							
	Underweight/Normal	-	-	-	200	157,263	74.5
	Overweight/Obese	-	-	-	83	53,966	25.5
Smoking Status (Adult)							
	Current/Previous Smoker	2,542	1,396,319	59.3	-	-	-
	Never Smoker	1,558	956,386	40.7	-	-	-
Smokers in the Home							
	Yes	708	407,822	17.1	67	49,370	7.1
	No	3,421	1,970,363	82.9	884	647,150	92.9
Walking for Transportation or Leisure							
	Yes	2,745	1,611,122	68.9	-	-	-
	No	1,317	727,414	31.1	-	-	-
Dogs/Cats in the Home (CHIS 2003)							
	Yes	1,945	1,030,316	43.3	391	266,096	38.2
	No	2,184	1,347,869	56.7	560	430,423	61.8
Cockroaches in the Home (CHIS 2003)							
	Yes	604	482,364	20.3	179	176,233	25.3
	No	3,525	1,895,821	79.7	772	520,286	74.7
Urban/Rural							
	Urban	1,619	1,039,998	43.7	358	295,795	42.5
	2nd city	1,146	623,796	26.2	272	174,321	25.0
	Suburban	547	387,498	16.3	162	141,262	20.3
	Town or Rural	817	326,893	13.7	159	85,141	12.2
Time at Current Address/Neighborhood							
	9 months-<1 yr	62	41,823	1.8	15	15,609	2.2
	1-<3 yr	651	424,912	17.9	302	249,010	35.8
	3+ yr	3,416	1,911,450	80.4	634	431,900	62.0
Household Crowding (CHIS 2003)							
	Yes	556	559,918	23.5	270	259,513	37.3
	No	3,573	1,818,266	76.5	681	437,007	62.7
Housing Type							
	House	2,710	1,500,907	63.1	691	478,939	68.8
	Apartment, Duplex, or Mobile Home	1,419	877,278	36.9	260	217,580	31.2

[a]For CHIS 2003, having asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived in the same home or neighborhood for at least 9 months were included.
[b]Representative of educational attainment level of the adult respondent or adult responding on behalf of the child.

Table 31. Disparities in weighted mean annual pollutant concentrations by various demographic characteristics in CHIS 2003 children and adults with asthma-like symptoms using bivariate analysis[a]

		NO_2 annual average (ppb)		O_3 annual average (ppb)		PM_{10} annual average (µg/m^3)		$PM_{2.5}$ annual average (µg/m^3)	
		Adults	Children	Adults	Children	Adults	Children	Adults	Children
Demographics		mean	mean	mean	mean	mean	mean	mean	mean
Household Federal Poverty Level	0 - 199 % FPL	23.3***	24.1	41.7	42.0	32.4***	30.9	17.4***	17.1*
	200 - 399 % FPL	21.1	20.8***	42.0	41.9	32.4*	29.5	16.4**	16.1
	≥400% FPL†	21.1	20.3	41.3	42.3	29.5	28.5	15.3	15.4
Race/ethnicity	Latino	24.3***	24.8***	41.4	40.6	33.7***	32.6*	18.2***	17.9**
	Alaskan Native / American	19.2	19.0	41.0	41.6	28.4	29.6	14.3	16.5
	Asian / Pacific Islander / Other	22.4*	21.3	41.0	44.4	28.1	27.5	15.1	14.6
	African American	23.3***	24.0*	38.9***	40.4	32.8**	28.0	17.3**	15.4
	White†	20.5	19.3	42.4	43.2	28.6	28.6	15.7	15.5
Urban/Rural	Urban†	24.7	25.6	38.8	39.0	29.2	29.0	16.6	16.8
	Second City	18.4***	18.0***	44.2***	44.2***	30.7*	28.9	15.9	14.6**
	Suburban	19.8***	19.9***	44.7***	45.3***	33.0***	33.9*	17.7*	17.8
	Town/Rural	11.0***	18.8**	48.1***	47.7***	26.0	28.6	10.1***	9.2***
Sex	Male	21.9	22.0	41.7	42.7	29.3*	29.5	16.2	16.5
	Female†	22.2	22.8	41.7	41.2	30.7	30.3	16.8	16.5
Age (in years)	0-5		21.7		41.3		28.9		16.0
	6-11		23.7		43.2		31.8		17.6
	12-17†		22.1		42.1		29.5		16.1
	18-34	22.2		41.6		30.3		16.8	
	35 - 64	22.0		41.8		30.1		16.4	
	65 and above†	21.8		41.4		29.7		16.3	

[a]For CHIS 2003, having asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.

†Reference Group

*p < 0.05, ** p < 0.01, *** p < 0.001

Table 32. Disparities in weighted prevalence of asthma-like symptoms by various demographic characteristics in CHIS 2003 children and adults using bivariate analysis[a]

		Wheeze		Missed ≥ 2 school/work days due to wheezing[b]		≥2 wheeze attacks[b]		Sought medical help for breathing problem	
		Adults	Children	Adults	Children	Adults	Children	Adults	Children
Demographics		%	%	%	%	%	%	%	%
Household Federal Poverty Level	0 - 199 % FPL	13.4***	9.4	17.3	45.2	60.4	54.8	41.9	65.1
	200 - 399 % FPL	11.7**	9.2	15.4	47.9	63.7	56.3	40.0	66.6
	≥400% FPL†	9.8	11.2	17.3	44.0	62.7	44.3	41.6	65.1
Race/ethnicity	Latino	9.8***	9.0	24.5***	50.7	51.7***	48.6	46.1*	69.1
	Alaskan Native / American Indian	26.4***	€	€	€	74.9	€	36.0	€
	Asian / Pacific Islander / Other	7.2***	10.6	11.6	29.6*	67.7	75.5***	43.0	56.6
	African American	13.2	10.3	17.6	52.5	62.4	€	49.0*	49.7
	White†	13.1	10.4	14.3	45.5	64.8	48.1	38.5	68.2
Urban/Rural	Urban†	11.0	9.9	16.8	43.3	62.2	48.9	43.3	65.6
	Second City	12.2*	9.4	18.9	51.4	61.8	62.2*	41.6	66.9
	Suburban	10.0	10.3	14.4	45.9	63.1	48.2	39.5	68.9
	Town/Rural	14.4***	10.1	16.1	40.9	60.9	47.8	36.5*	56.6
Sex	Male	11.6	10.9*	13.6***	42.7	62.9	51.7	32.8***	65.7
	Female†	11.3	8.9	20.3	48.6	61.1	51.8	50.3	65.2
Age	0-5		14.0***		44.8		46.7*		82.8***
	6-11		8.0		46.4		59.1		73.6***
	12-17†		8.4		-		-		34.2
	18-34	10.7		18.3		59.2		35.5***	
	35 - 64	12.0		17.0		63.1		42.7	
	65 and above†	11.1		€		64.0		48.6	

[a]For CHIS 2003, having asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived in the same home or neighborhood for at least 9 months were included.
[b]Data not collected for teen respondents.
†Reference Group
€ Unstable values (CV > 30%)
*p < 0.05, ** p < 0.01, *** p < 0.001

Table 33 (Detailed). Associations (OR (95% CI)) for 12-month pollutant averages and asthma-like outcomes in CHIS 2003 adults and children with asthma-like symptoms[a]

	Wheeze				Missed ≥2 School/Work Days Due to Wheezing[b]				≥2 Wheeze Attacks[b]				Sought Medical Help for Breathing Problem			
Pollutant	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.
Adults																
O_3 (per 10 ppb)	2,044	14,824	**1.09**	[1.01, 1.18]	258	1,296	0.91	[0.74, 1.12]	1,121	657	1.11	[0.94, 1.30]	739	1,039	1.06	[0.91, 1.24]
PM_{10} (per 10 μg/m^3)	1,614	11,229	**1.09**	[1.01, 1.18]	198	1,027	0.84	[0.66, 1.06]	912	488	1.10	[0.94, 1.29]	577	823	1.09	[0.94, 1.27]
$PM_{2.5}$ (per 5 μg/m^3)	1,253	9,331	1.07	[0.97, 1.17]	162	797	0.88	[0.69, 1.12]	691	396	1.00	[0.83, 1.19]	462	625	1.06	[0.89, 1.26]
NO_2 (per 10 ppb)	1,687	12,534	0.93	[0.86, 1.02]	222	1,061	0.73	[0.56, 0.96]	905	566	1.09	[0.91, 1.30]	622	849	0.93	[0.78, 1.11]
Children																
O_3 (per 10 ppb)	441	4,109	1.09	[0.92, 1.29]	143	167	0.96	[0.67, 1.36]	157	153	1.29	[0.92, 1.81]	295	146	0.99	[0.72, 1.36]
PM_{10} (per 10 μg/m^3)	348	3,102	0.95	[0.80, 1.13]	112	129	0.75	[0.53, 1.07]	113	128	1.15	[0.82, 1.60]	223	125	0.80	[0.58, 1.10]
$PM_{2.5}$ (per 5 μg/m^3)	274	2,601	0.97	[0.80, 1.18]	87	107	0.90	[0.59, 1.37]	97	97	1.25	[0.86, 1.82]	172	102	1.16	[0.73, 1.83]
NO_2 (per 10 ppb)	364	3,504	0.94	[0.79, 1.11]	113	146	1.25	[0.82, 1.90]	134	125	1.02	[0.69, 1.50]	243	121	1.33	[0.90, 1.98]

[a]For CHIS 2003, having asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b]Data not collected for teen respondents.
[c]Adjusted for age, race, poverty level, and sex.

Table 34. Associations (OR (95% CI)) for annual days exceeding air pollution standards and asthma-like outcomes comparing quartiles in CHIS 2003 adults and children with asthma-like symptoms[a]

	Wheeze				Missed ≥2 School/Work Days Due to Wheezing[b]				≥2 Wheeze Attacks[b]				Sought Medical Help for Breathing Problem			
Exceedances in days	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.
Adults																
O_3 1-Hr (State) - Ref. < 0.8 days																
0.8 days < 8.7 days	489	3,892	0.84	[0.70, 1.00]	63	306	1.10	[0.65, 1.84]	257	167	1.13	[0.78, 1.63]	189	235	0.98	[0.68, 1.42]
8.7 days - < 36.7 days	579	4,215	0.835	[0.70, 0.99]	76	369	0.777	[0.48, 1.27]	341	169	1.32	[0.92, 1.89]	193	317	0.74	[0.52, 1.05]
≥ 36.7 days	507	3,577	1.01	[0.85, 1.21]	56	334	0.73	[0.44, 1.23]	284	157	1.29	[0.89, 1.86]	181	260	0.90	[0.63, 1.30]
O_3 8-Hr (State) - Ref. < 1.9 days																
1.9 days - <14.3 days	479	3,752	0.88	[0.74, 1.05]	63	297	0.97	[0.58, 1.62]	249	167	1.16	[0.81, 1.67]	181	235	0.90	[0.62, 1.28]
14.3 days - < 51.2 days	539	4,110	0.91	[0.77, 1.08]	76	336	0.86	[0.52, 1.40]	311	152	1.42	[0.99, 2.04]	180	283	0.78	[0.55, 1.11]
≥ 51.2 days	562	3,526	1.16	[0.97, 1.38]	63	368	0.73	[0.43, 1.24]	320	174	1.30	[0.91, 1.87]	204	290	0.96	[0.67, 1.38]
PM_{10} (State) - Ref. < 1.6 days																
1.6 days - < 3.5 days	383	2,850	1.01	[0.84, 1.22]	53	250	1.10	[0.62, 1.94]	218	126	0.96	[0.64, 1.44]	142	202	0.96	[0.64, 1.43]
3.5 days - <6.6 days	301	2,405	0.90	[0.73, 1.11]	40	193	0.61	[0.33, 1.16]	177	83	1.07	[0.69, 1.67]	111	149	0.87	[0.56, 1.35]
≥ 6.6 days	490	2,864	**1.26**	[1.04, 1.53]	60	321	0.60	[0.33, 1.09]	279	146	0.99	[0.65, 1.49]	182	243	1.20	[0.80, 1.80]
$PM_{2.5}$ (Federal) - Ref. < 4.8 days																
4.8 days - < 12.0 days	258	1,897	1.15	[0.91, 1.46]	29	167	0.81	[0.41, 1.62]	151	76	1.13	[0.69, 1.87]	93	134	1.06	[0.65, 1.73]
12.0 days - < 24.9 days	391	2,839	1.16	[0.93, 1.44]	46	253	0.69	[0.38, 1.28]	198	137	0.78	[0.49, 1.24]	145	190	1.12	[0.73, 1.73]
≥ 24.9 days	301	2,263	1.07	[0.85, 1.35]	48	194	0.91	[0.49, 1.71]	177	90	1.09	[0.67, 1.76]	114	153	1.09	[0.70, 1.72]
Children																
O_3 1-Hr (State) - Ref. < 0.8 days																
0.8 days < 8.7 days	114	1,056	1.19	[0.81, 1.74]	35	42	1.24	[0.50, 3.07]	40	37	**2.79**	[1.10, 7.10]	74	40	0.70	[0.32, 1.54]
8.7 days - < 36.7 days	128	1,161	1.24	[0.85, 1.81]	44	47	1.62	[0.70, 3.77]	40	51	1.87	[0.78, 4.53]	84	44	0.86	[0.37, 2.00]
≥ 36.7 days	110	1,069	1.19	[0.86,1.73]	33	46	1.14	[0.49, 2.62]	55	24	**3.98**	[1.56, 10.11]	74	36	0.93	[0.41, 2.10]
O_3 8-Hr (State) - Ref. < 1.9 days																
1.9 days - <14.3 days	110	1,018	1.34	[0.92, 1.96]	33	39	1.24	[0.52, 2.98]	30	42	1.25	[0.50, 3.09]	76	34	1.29	[0.59, 2.81]
14.3 days - < 51.2 days	116	1,110	1.20	[0.83, 1.75]	42	43	**2.35**	[1.01, 5.47]	42	43	1.71	[0.75, 3.93]	79	37	1.26	[0.57, 2.80]
≥ 51.2 days	123	1,086	1.32	[0.91, 1.91]	37	50	0.98	[0.43, 2.19]	55	32	1.80	[0.77, 4.20]	79	44	1.12	[0.53, 2.38]
PM_{10} (State) - Ref. < 1.6 days																
1.6 days - < 3.5 days	88	692	1.21	[0.80, 1.83]	30	28	1.60	[0.56, 4.55]	218	126	0.96	[0.64, 1.44]	60	28	1.28	[0.51, 3.26]
3.5 days - <6.6 days	77	651	1.38	[0.87, 2.18]	31	32	1.10	[0.40, 3.08]	177	83	1.07	[0.69, 1.67]	53	24	0.70	[0.27, 1.81]
≥ 6.6 days	106	948	1.08	[0.70, 1.67]	26	45	0.56	[0.22, 1.46]	34	37	0.65	[0.24, 1.75]	61	45	0.67	[0.26, 1.71]
$PM_{2.5}$ (Federal) - Ref. < 4.8 days																
4.8 days - < 12.0 days	57	493	1.62	[0.99, 2.65]	12	22	0.37	[0.13, 1.10]	151	76	1.13	[0.69, 1.87]	33	24	1.28	[0.41, 4.04]
12.0 days - < 24.9 days	78	753	1.26	[0.81, 1.95]	27	28	0.77	[0.29, 2.07]	198	137	0.78	[0.49, 1.24]	55	23	1.75	[0.67, 4.57]
≥ 24.9 days	66	633	1.19	[0.73, 1.95]	22	33	0.64	[0.24, 1.76]	31	24	1.30	[0.49, 3.48]	40	26	0.79	[0.30, 2.09]

[a]For CHIS 2003, having asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.

[b]Data not collected for teen respondents

[c]Adjusted for age, race, poverty level, and sex.

Table35. Associations (OR (95% CI)) for traffic density/distance to roadway and asthma-like outcomes in CHIS 2003 adults and children with asthma-like symptoms[a]

	Wheeze				Missed ≥2 School/Work Days Due to Wheezing[b]				≥2 Wheeze Attacks[b]				Sought Medical Help for Breathing Problem			
Exposure	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.	Cases	Non-Cases	OR[c]	95% C.I.
Adults																
Tele Atlas Traffic < 750ft (25th < 50th percentile)[d,e]	967	6,702	1.07	[0.93, 1.22]	122	623	1.22	[0.83, 1.79]	542	320	0.82	[0.62, 1.09]	358	504	1.23	[0.94, 1.62]
Tele Atlas Traffic < 750ft (50th < 75th percentile)[d,e]	880	6,328	1.04	[0.90, 1.19]	116	562	1.28	[0.86, 1.90]	500	260	1.02	[0.76, 1.35]	325	435	1.30	[0.99, 1.71]
Tele Atlas Traffic < 750ft (≥75th percentile)[d,e]	824	6,194	0.98	[0.85, 1.13]	101	535	0.98	[0.65, 1.49]	447	271	0.91	[0.67, 1.22]	297	421	1.07	[0.80, 1.43]
State Highway < 300 m	189	1,158	1.10	[0.89, 1.37]	19	125	0.64	[0.35, 1.18]	111	52	1.13	[0.70, 1.83]	64	99	1.21	[0.79, 1.84]
Interstate Highway < 300 m	344	2,552	1.00	[0.84, 1.19]	41	224	0.75	[0.46, 1.23]	184	119	0.78	[0.55, 1.11]	112	191	0.77	[0.53, 1.12]
Major Road < 50 m	717	4,923	0.99	[0.88, 1.12]	93	451	1.10	[0.77, 1.57]	404	211	1.16	[0.89, 1.51]	251	364	0.93	[0.72, 1.20]
Children																
Tele Atlas Traffic < 750ft (25th < 50th percentile)[d,e]	205	2,036	0.87	[0.65, 1.15]	64	75	1.07	[0.58, 1.99]	79	60	**2.15**	[1.10, 4.21]	134	71	1.46	[0.74, 2.90]
Tele Atlas Traffic < 750ft (50th < 75th percentile)[d,e]	205	1,859	0.71	[0.53, 0.93]	68	76	0.89	[0.48, 1.65]	69	75	1.57	[0.84, 2.96]	139	66	0.80	[0.42, 1.50]
Tele Atlas Traffic < 750ft (≥75th percentile)[d,e]	187	1,572	0.92	[0.68, 1.23]	64	66	1.20	[0.63, 2.30]	60	70	1.39	[0.72, 2.71]	130	57	0.91	[0.48, 1.73]
State Highway < 300 m	46	310	1.03	[0.65, 1.63]	12	19	0.59	[0.21, 1.65]	14	17	0.62	[0.24, 1.64]	30	16	0.98	[0.41, 2.31]
Interstate Highway < 300 m	81	700	1.09	[0.76, 1.58]	35	24	1.69	[0.76, 3.76]	34	25	**2.55**	[1.16, 5.57]	53	28	0.51	[0.23, 1.17]
Major Road < 50 m	150	1,263	0.93	[0.70, 1.23]	58	51	1.73	[0.98, 3.07]	52	57	0.89	[0.50, 1.57]	107	43	0.85	[0.49, 1.47]

[a]For CHIS 2003, asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived in the same home or neighborhood for at least 9 months, and geocoded by address or nearest cross streets were included. Measures based on Tele Atlas traffic data.

[b]Data not collected for teen respondents

[c]Adjusted for age, race, poverty level, and sex.

[d]Reference: <25th percentile

[e]Units: vehicle meters traveled/day/meter^2

Table 36 (Detailed). Associations between two or more wheeze attacks and O_3 adjusting for vulnerability characteristics among CHIS adults with asthma-like symptoms[a]

		Model 1 (1121, 657)[b]			Model 2 (1115, 652)[b]			Model 3 (1105, 647)[b]		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
O_3 12-Month Average (per 10 ppb)		1.11	0.94	1.30	1.12	0.95	1.32	1.12	0.95	1.31
Age (Ref. ≥65)										
	18 - 34	0.85	0.57	1.27	1.17	0.72	1.88	0.63	0.40	0.98
	35 - 64	1.22	0.86	1.72	1.63	1.08	2.44	0.98	0.68	1.41
Race (Ref. White)										
	African American	0.94	0.57	1.54	0.97	0.59	1.62	1.05	0.62	1.77
	AI/AN	1.83	0.73	4.59	2.00	0.78	5.17	1.85	0.72	4.79
	Asian / PI / Other	1.02	0.63	1.65	1.08	0.67	1.73	1.07	0.64	1.78
	Latino	0.56	0.39	0.78	0.57	0.39	0.82	0.64	0.44	0.94
Poverty (Ref. ≥400%)										
	0 - 199% FPL	1.05	0.76	1.45	0.82	0.58	1.17	0.98	0.69	1.40
	200 - 399% FPL	0.92	0.67	1.27	0.84	0.60	1.16	0.86	0.62	1.19
Sex										
	Female vs. Male	0.99	0.76	1.28	0.96	0.73	1.26	0.94	0.71	1.23
Currently Insured										
	Yes vs No				0.71	0.50	1.02			
Obese										
	No vs Yes				0.94	0.70	1.25			
Heart Disease										
	Yes vs No				1.28	0.84	1.94			
Smoker										
	Ever vs Never				1.43	1.08	1.88			
Work Status										
	Employed vs Unemployed				0.52	0.37	0.73			
Urban/Rural (Ref. Town and Rural)										
	Urban							1.63	0.88	3.02
	2nd City							1.40	0.75	2.62
	Suburban							1.55	0.80	3.01
Usual Source of Care										
	Yes vs No							1.03	0.70	1.53
Delay in Care										
	Yes vs No							0.58	0.43	0.80
Household Smoking										
	No vs Yes							0.54	0.37	0.79
Dog or Cat in Home										
	No vs Yes							0.82	0.62	1.10
Cockroaches										
	Yes vs No							0.96	0.66	1.40
Housing type (Ref. House)										
	Duplex or Apartment							0.68	0.32	1.46
	Mobile Home							0.65	0.31	1.38
Household Crowding										
	No vs Yes							0.95	0.65	1.40
Diabetes (Ref. Pre-Diabetes/ Borderline										
	Yes							0.62	0.17	2.21
	No							0.75	0.22	2.53
Walking										
	Yes vs No							0.99	0.74	1.32

[a]For CHIS 2003, asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.

[b](Cases, Controls)

Table 37. Associations between two or more wheeze attacks and vulnerability characteristics by O_3 among CHIS children with asthma-like symptoms[a]

		O_3 (per 10 ppb) (157, 153)[b]								
		Model 1			Model 2			Model 3		
Vulnerability Characteristic		OR	95% C.I.		OR	95% C.I.		OR	95% C.I.	
12-Month Average		1.29	0.90	1.84	1.28	0.89	1.83	1.27	0.86	1.89
Age (Ref. 6-11 years)										
	< 6 years old	0.66	0.35	1.25	0.69	0.37	1.29	0.65	0.34	1.25
Race (Ref. White)										
	African American	0.32	0.06	1.69	0.26	0.04	1.60	0.38	0.08	1.81
	AI/AN	0.21	0.03	1.54	0.18	0.03	1.16	0.16	0.02	1.53
	Asian / PI / Other	2.07	0.77	5.57	1.84	0.69	4.91	2.55	0.88	7.41
	Latino	0.53	0.25	1.15	0.46	0.20	1.07	0.75	0.34	1.65
Poverty (Ref. ≥400%)										
	0 - 199% FPL	3.44	1.60	7.38	3.62	1.59	8.23	4.88	2.05	11.63
	200 - 399% FPL	2.42	1.06	5.55	2.40	1.06	5.47	2.61	1.10	6.23
Sex										
	Female vs. Male	0.93	0.52	1.69	0.88	0.49	1.59	0.93	0.49	1.75
Household Smoking										
	No vs Yes				0.55	0.12	2.47			
Dog or Cat in Home										
	No vs Yes				1.11	0.56	2.22			
Cockroaches										
	Yes vs No				0.73	0.36	1.47			
Currently Insured										
	Yes vs No				0.38	0.11	1.26			
Urban/Rural (Ref. Town and Rural)										
	Urban							1.20	0.36	3.95
	2nd City							1.19	0.37	3.83
	Suburban							0.92	0.26	3.19
Delay in Care										
	No vs Yes							0.43	0.15	1.20
Housing type (Ref. House										
	Duplex or Apartment							0.38	0.04	3.71
	Mobile Home							0.59	0.06	6.23
Household Crowding										
	No vs Yes							2.32	1.02	5.27

[a]For CHIS 2003, asthma-like symptoms is defined as reporting wheezing or whistling in the previous 12 months without an asthma diagnosis; only respondents who lived within 5 miles of an air monitoring station and lived in the same home or neighborhood for at least 9 months were included.
[b](Cases, Controls)

Summary of Findings for CHIS 2003 Respondents with Current Asthma

Demographic/Descriptive

- One-third of adults (32.5%) and more than a third of children (38.4%) with current asthma lived below 200% of the FPL.
- About 40% of adults and more than half of children (56.5%) with current asthma were minorities.

Pollutant Exposure Disparities

Adults

- In general, adult respondents with current asthma living below 200% of the FPL had higher estimates of annual average exposure to NO_2, PM_{10}, and $PM_{2.5}$, than those living at or above 400% of the FPL.
- Adult respondents in minority populations had higher estimated exposures to several criteria pollutants. Specifically, Latino adults had higher estimated exposures to NO_2, PM_{10}, and $PM_{2.5}$; African American adults had higher estimated exposures to $PM_{2.5}$; and Asian/PI/Other adults had higher estimated exposures to NO_2 compared to white respondents. However, they all had lower O_3 exposures than their white counterparts.
- African American Adults were more likely to live in areas with higher traffic density than white adults.

Children

- On average, children with current asthma living between 0-199% of the FPL had a higher estimated mean annual exposure to criteria pollutants (NO_2, PM_{10}, and $PM_{2.5}$) and were more likely to live in places with greater traffic density or live near highways or major roadways than children living at or above 400% of the FPL.
- Minority children had higher estimated mean annual exposures to several criteria pollutants. Specifically, Latino and African American children had higher estimated mean annual exposures to NO_2 and $PM_{2.5}$, and Asian/PI/Other children had higher estimated exposure to NO_2.
- Mean traffic density measures were higher for both Latino and African American children than for white children.

Associations of Air Pollution Exposure with Asthma Outcomes

Adults

- We observed increased odds of experiencing an asthma attack in the previous year among adults with lifetime asthma.
- We observed increased odds of ED visits, using daily asthma medication, and missing 2 or more days of work due to asthma with the increase in annual average O_3, PM_{10}, and $PM_{2.5}$ among adults with current asthma.

Children

- We observed increased odds of daily asthma medication use and missing 2 or more days of school/day care with the increase of annual average NO_2.

Associations of Exceedance Days with Asthma Outcomes

Adults

- Exceedances of state 1-hr O_3 standards (i.e. over 36.7 days per year) were associated with increased odds for asthma attacks among adults with lifetime asthma, and visiting the ED and using a daily asthma medication among adults with current asthma.
- Exceedances of the state 24-hr PM_{10} standard (i.e. over 6.6 days per year) were associated with increased odds of asthma ED visits.
- Exceedances of the federal 24-hr $PM_{2.5}$ standard (i.e. over 23.9 days per year) were associated with increased odds of ED visits and daily/weekly asthma symptoms.

Children

- O_3 exceedances (state 1-hr standard) were associated with increased odds of missing 2 or more days of school.

Association of Traffic Measures with Asthma Outcomes

- An interquartile increase in traffic density within 750 feet of respondent's homes was associated with an increase in odds of reporting asthma ED visits in the past year among adults with current asthma.
- Living within 300 m of an interstate highway was associated with a suggested increase in the odds of visiting the ED in the past year, as well as a suggested increase in the odds of needing a daily asthma medication among adults.

Vulnerability Factors

Adults

- Positive associations between pollutants (O_3, PM_{10}, and $PM_{2.5}$) and asthma outcomes (ED visits, taking a daily asthma medication, or missing 2 or more days of work) persisted after adjusting for potential vulnerability factors.
- In addition to pollutant exposures, several other characteristics were related to increased odds of asthma outcomes: being African American or Latino, living below 200% of the FPL,, being a smoker, having heart disease and having adult onset asthma.
- Some characteristics, such as, not having an asthma management plan and using daily asthma medication, decreased odds of ED visits or missing 2 or more days of work. :.

Children

- Positive associations between daily asthma medication and $PM_{2.5}$ persisted after adjusting for potential vulnerability factors.
- Children living below 200% and between 200-399% of the FPL consistently had higher odds of using a daily asthma medication than those living at or above 400% of the FPL.
- Not having an asthma management plan decreased odds of using daily asthma medication.

Interactions

Adults

- For the same level of increase in annual average NO_2, African American and Asian/PI/other adults had greater increases in missing two or more days of work due to asthma compared to white adults.
- African American adults had a greater increase in daily/weekly asthma symptoms for the same level of increase in annual average NO_2.

Children

- For the same level of increase in annual average NO_2, American Indian/Alaska Native and Asian/PI/other children had greater increases in daily/weekly symptoms compared to white children.
- Latino children had a greater increase in using daily asthma medication, and African-American and Asian/PI/other children had a greater increase in experiencing daily/weekly symptoms for the same increase in annual average PM_{10} as white children.
- Children living below 200% of the FPL had a greater increase in ED visits compared to those living at or above 400% of the FPL for the same increase in annual average NO_2.

Summary of Findings for CHIS 2003 Respondents with Asthma-like Symptoms

Demographic/Descriptive

Adults

- 41.5% of adults with asthma-like symptoms were minorities.
- More than one-third (39.0%) of adults with asthma-like symptoms lived below 200% of the FPL.

Children

- 57.4% of children with asthma-like symptoms were minorities.
- Children with asthma-like symptoms fell below 200% of the FPL 42.4% of the time.

Pollutant Exposure Disparities

Adults

- In comparison to those living at 400% of the FPL or above, adultswith asthma-like symptoms living below 200% of the FPL had higher estimated average annual exposure to all criteria pollutants except for O_3.
- Latino and African American adults had higher estimated average annual exposure to all criteria pollutants except for O_3 than white adults.

Children

- In comparison to those living at 400% of the FPL or above, children with asthma-like symptoms living below 200% of the FPL had higher estimated average annual exposure to NO_2 and $PM_{2.5}$.
- Latino and African American children had higher annual average concentrations of NO_2 than white children.
- Latino children also had higher annual average concentrations of PM_{10} and $PM_{2.5}$ than white children.

Associations between Air Pollution Exposure and Asthma-like Symptoms

Adults

- Increases in O_3, PM_{10}, and $PM_{2.5}$ annual averages were associated with increased odds of wheeze.
- Increases in O_3 and PM_{10} annual averages appeared to be associated with having 2 or more wheeze attacks.

Children

- Increased annual average O_3 appeared to be associated with increased odds of wheeze and having 2 or more wheeze attacks.