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Associations between urban air pollution and pediatric asthma control in El Paso, Texas

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HIGHLIGHTS

- We examined weekly associations between asthma control scores and air pollution.
- The Asthma Control Questionnaire (ACQ) was used as a metric of asthma control.
- We found positive, albeit non-significant associations for many pollutants.
- Significant associations existed among subjects taking inhaled corticosteroids.
- The ACQ can reflect biologically relevant changes in control from poor air quality.

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ABSTRACT

Exposure to traffic-related pollutants poses a serious health threat to residents of major urban centers around the world. In El Paso, Texas, this problem is exacerbated by the region's arid weather, frequent temperature inversions, heavy border traffic, and an aged, poorly maintained vehicle fleet. The impact of exposure to traffic pollution, particularly on children with asthma, is poorly understood. Tracking the environmental health burden related to traffic pollution in El Paso is difficult, especially within school microenvironments, because of the lack of sensitive environmental health indicator data. The Asthma Control Questionnaire (ACQ) is a survey tool for the measurement of overall asthma control, yet has not previously been considered as an outcome in air pollution health effect research. We conducted a repeated measure panel study to examine weekly associations between ACQ scores and traffic- and non-traffic air pollutants among asthmatic schoolchildren in El Paso. In the main one- and two-pollutant epidemiologic models, we found non-significant, albeit suggestive, positive associations between ACQ scores and respirable particulate matter (PM_{10}), coarse particulate matter ($PM_{10-2.5}$), fine particulate matter ($PM_{2.5}$), black carbon (BC), nitrogen dioxide (NO_2), benzene, toluene, and ozone (O_3). Notably, associations were stronger and significant for some subgroups, in particular among subjects taking daily inhaled corticosteroids. This pattern may indicate heightened immune system response in more severe asthmatics, those with worse asthma "control" and higher ACQ scores at baseline. If the ACQ is appropriately used in the context of air pollution studies, it could reflect clinically measurable and biologically relevant changes in lung function and asthma symptoms that result from poor air quality and may increase our understanding of how air pollution influences asthma exacerbation.

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1. Introduction

In 2009, 7.1 million children within the United States (9.6% of individuals 0–17 years of age) were estimated to suffer from asthma (Akinbami et al., 2011), a chronic inflammatory disease of the airways with the potential for acute worsening of symptoms in response to environmental exposures. Short-term increases in traffic-related air pollutants such as fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), black carbon (BC), benzene, and toluene have been associated with a range of health responses including increased adverse respiratory symptoms (Delfino et al., 2003a; Escamilla-Nunez et al., 2008; Gent et al., 2009; Mann et al., 2010; Ostro et al., 2001; Spira-Cohen et al., 2011), emergency room visits and hospital admissions (Barnett et al.,

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2005; Friedman et al., 2001; Halonen et al., 2008; Hirshon et al., 2008; Strickland et al., 2010; Tolbert et al., 2000; White et al., 1994), and decreased lung function (Barraza-Villarreal et al., 2008; Dales et al., 2009; Delfino et al., 2003b, 2008; Liu et al., 2009). In addition, residential proximity to roadways and heavy traffic has been associated with decreased lung function (Holguin et al., 2007; Rosenlund et al., 2009) and increased hospital utilization (Chang et al., 2009; Wilhelm et al., 2008) among children with asthma. Among asthmatics, socioeconomic status (SES) (Gold and Wright, 2005; Goodman et al., 1998; Meng et al., 2008; Neidell, 2004; Ray et al., 1998), atopy (Mann et al., 2010), and inhaled corticosteroid (ICS) use (Delfino et al., 1998) have also been shown to modify air pollution-related outcomes.

The Paso del Norte (PdN) region along the United States–Mexico border has several unique geographic and demographic features that make it an important region for the investigation of traffic pollution and asthma response among children in North America. It was estimated that 10 million passenger cars and over 700,000 trucks passed through the portal city of El Paso into Mexico in 2010 (U.S. Department of Transportation RaITA, Bureau of Transportation Statistics, 2010). In addition, elevated sunlight intensities, sustained temperature inversions, an older, poorly maintained vehicle fleet, and infrequent rainfall all contribute to poor urban air quality within the greater El Paso area (Li et al., 1999, 2001; Parks et al., 2002). Previous investigations (Hart et al., 1999), including two studies conducted by our group (Sarnat et al., 2012; Li et al., 2011), have linked short-term exposures to various air pollutants and respiratory health among asthmatic children in the PdN region. In our 2008 study (Sarnat et al., 2012) of 58 asthmatic schoolchildren living in El Paso and Ciudad Juarez, Mexico, we reported interquartile range (IQR) increases in $PM_{2.5}$, PM_{10}, $PM_{10-2.5}$, NO_2, and BC to be positively and significantly associated with exhaled nitric oxide (eNO), a biomarker of pulmonary inflammation in asthmatics. In a follow-up study conducted in 2010 (Li et al., 2011), we examined associations between pollution and a broader range of potential biological response, including inflammation, medication usage, symptom reporting and lung function in 38 asthmatic children from two El Paso elementary schools. As with our 2008 study, we found associations between levels of several traffic-related outdoor air pollutants and eNO, including particulate BC and gas phase benzene. Outdoor benzene levels, along with other volatile organic compounds (VOCs) were also negatively and significantly associated with decrements in lung function, expressed as forced expiratory volume in 1 s (FEV_1). We did not observe any associations between the pollutants and self-reported symptoms in either of the studies.

Although previous studies have implicated components of traffic pollution with asthma response in children, finding clear associations within the epidemiological results has been challenging given the diverse range of pollutants and biological responses examined. Most studies of air pollution and asthma typically examine associations in a univariate or two-pollutant setting as predictors of a single, specific response class (i.e., either lung function or symptom reporting, for example). Examining aggregate response across a range of health endpoints, however, may offer novel insight into potential causal agents and asthma etiology.

In our 2010 study, we administered the Asthma Control Questionnaire (ACQ) to each of our subjects on weekly basis for a 13 week study period (Li et al., 2011). The ACQ is a seven question survey tool intended for use in clinical settings to assess differences in asthma status related to treatment therapy, efficacy of treatment, or response to treatment. It was initially developed for adults (Juniper et al., 1999), but has been subsequently validated for use among children 6–16 years of age (Juniper et al., 2010). ACQ questions score respiratory symptoms (4 questions), activity limitation (1 question), use of short-acting beta agonist (1 question) over the previous week, as well as the percent predicted FEV_1 at the time of the questionnaire based on age, gender, race, and height. Higher individual ACQ scores are thought to represent reduced asthma "control" that may warrant increased short-term or long-term medical intervention.

Asthma control as a health outcome, assessed through the ACQ, represents a health metric that, to our knowledge has not been previously used in air pollution studies either in children or adults. Moreover, modeling ACQ as an outcome provides a unique means of assessing a range of acute asthmatic responses, including symptom occurrence, medication usage, and lung function simultaneously instead of separately as has been done previously. Additionally, the ACQ is a clinically relevant tool that allows for quantification of asthma status in a consistent and repeatable manner. In this analysis, we examine associations between ACQ scores and weekly traffic- and non-traffic related air pollutants among asthmatic children in El Paso, and address the potential implications of these findings for understanding pollution-derived asthma risk.

2. Material and methods

2.1. Study overview

This study was conducted in El Paso, Texas from March to June, 2010 at two elementary schools (Li et al., 2011), both of which participated in the 2008 study (Sarnat et al., 2012). School 1 was located in a "high traffic" area within 300 ft of principal arterial or high-service, capacity-controlled access roadways, with heavy truck traffic. School 2 was located in a "low traffic" area adjacent to local surface streets exclusively. The study consisted of weekly repeated measurements of health outcomes, air pollution, and meteorology over a 13 week study period, which spanned from the spring to early summertime. Baseline data (related to asthma medication use, symptoms, activity limitation, prior emergency room visits and hospital admissions) was collected from parents on March 5, 2010. Outdoor pollutant measurements and meteorological data were aggregated for the weeks leading up to the Fridays March 12, 2010 to June 4, 2010 (data for several pollutants were not collected during the week of spring break for both schools and during the final collection week). Weekly health outcome sampling occurred on these Fridays at each school during that time period (data not collected during the week of spring break for both schools). The protocol for this study was approved by the International Review Board of Emory University prior to subject recruitment and data collection.

2.2. Subject recruitment

At each school, children were recruited to participate in the study through school nurses. A legal guardian for each child provided written consent; children greater than or equal to 11 years of age provided written assent, while younger children provided verbal assent. Consent and assent forms were provided in both English and Spanish. Eligibility criteria included age between 6 and 12, a physician diagnosis of asthma, no other lung disease or major illness, a non-smoking household, and residence proximal to their school. Among the 38 subjects who completed the study protocol, one subject from School 1 was excluded from the current analysis due to missing information related to ACQ scoring, and one subject from School 2 was excluded due to a lack of data regarding current asthma medication use. The current analysis is based on19 children who attended School 1 and 17 children who attended School 2.

2.3. Exposure and meteorological measurements

Air pollutants, including size resolved particles, gases, and speciated volatile organic compounds were measured for 96-hour Mondays–Fridays outdoors and indoors at each school as a metric of weekly pollutant exposures preceding the Friday survey date each week. Concentrations in the PdN region have been shown to vary by school

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