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Associations between environmental quality and adult asthma prevalence in medical claims data

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ABSTRACT

As of 2014, approximately 7.4% of U.S. adults had current asthma. The etiology of asthma is complex, involving genetics, behavior, and environmental factors. To explore the association between cumulative environmental quality and asthma prevalence in U.S. adults, we linked the U.S. Environmental Protection Agency's Environmental Quality Index (EQI) to the MarketScan® Commercial Claims and Encounters Database. The EQI is a summary measure of five environmental domains (air, water, land, built, sociodemographic). We defined asthma as having at least 2 claims during the study period, 2003–2013. We used a Bayesian approach with non-informative priors, implementing mixed-effects regression modeling with a Poisson link function. Fixed effects variables were EQI, sex, race, and age. Random effects were counties. We modeled quintiles of the EQI comparing higher quintiles (worse quality) to lowest quintile (best quality) to estimate prevalence ratios (PR) and credible intervals (CIs). We estimated associations using the cumulative EQI and domain-specific EQIs; we assessed U.S. overall (non-stratified) as well as stratified by rural-urban continuum codes (RUCC) to assess rural/urban heterogeneity. Among the 71,577,118 U.S. adults with medical claims who could be geocoded to county of residence, 1,147,564 (1.6%) met the asthma definition. Worse environmental quality was associated with increased asthma prevalence using the non-RUCC-stratified cumulative EQI, comparing the worst to best EQI quintile (PR:1.27; 95% CI: 1.21, 1.34). Patterns varied among different EQI domains, as well as by rural/urban status. Poor environmental quality may increase asthma prevalence, but domain-specific drivers may operate differently depending on rural/urban status.

Abbreviations: CI, confidence interval; EQI, environmental quality index; IRB, institutional review board; MCMC, monte carlo markov chain; PCA, principal component analysis; PR, prevalence ratio; RUCC, rural urban continuum codes; U.S., United States

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1. Introduction

Asthma is a chronic respiratory condition characterized by wheezing, shortness of breath, tightness in the chest, and coughing that results from swollen and narrowed airways (US Department of Health and Human Services, 2016). From 2001–2009, asthma prevalence in the United States (U.S.) increased 12.3% (CDC, 2011), leading to 479,300 hospitalizations and 1.9 million emergency room visits in 2009 (U.S. Centers for Disease Control and Prevention, 2016). The overall cost of asthma, including medical costs and lost productivity due to both morbidity and mortality was $56 billion in 2007 (Barnett and Nurmagambetov, 2011). As of 2014, the prevalence of asthma among U.S. adults was approximately 7.4% (U.S. Centers for Disease Control and Prevention, 2014).

Adults may have been diagnosed with asthma as children or may develop it in adulthood. Family history of asthma and atopy, a genetic predisposition to reaction to environmental allergens, increase the risk of asthma, but are more predictive of early-onset asthma in childhood (U.S. Centers for Disease Control and Prevention, 2014; London et al., 2001). In adults, lower educational attainment and lower household income are associated with increased likelihood of having asthma (U.S. Centers for Disease Control and Prevention, 2016; Bacon et al., 2009). Behavior such as smoking and comorbidities such as obesity and depression are also risk factors for asthma in adults (U.S. Centers for Disease Control and Prevention, 2014; Brunner et al., 2014; Kapadia et al., 2014).

Increasingly, environmental conditions have also been linked to asthma. Ambient air pollution has been associated with incident asthma in U.S. women (Young et al., 2014), asthma-related emergency room visits (Newman et al., 2014) and asthma risk in minorities (Nishimura et al., 2013), and a meta-analysis of six European cohorts indicated air pollution may be associated with adult-onset asthma (Jacquemin et al., 2015). In the early 2000s, the built environment was targeted for policy and research to investigate its role in asthma prevalence (Brisbon et al., 2005; Cummins and Jackson, 2001). Subsequent studies yielded mixed results. For example, proximity of green areas or tree density near homes has been associated with reductions in atopic sensitization or lower asthma prevalence in some studies of children (Ruokolainen et al., 2015; Lovasi et al., 2008), but associated with increased current asthma in others (Dadvand et al., 2014; Andrusaityte et al., 2016). Exposure to land use contaminants such as living near an industrial park or concentrated animal feeding operation has been associated with increased risk of asthma in adults (Al-Wahaibi and Zeka, 2015; Radon et al., 2007). Similarly, water quality provides another potential mechanism for exposure; for example, deposition of nitrates in water has been associated with respiratory tract infections (Gupta et al., 2000).

In short, asthma is a complex condition that is dependent on numerous individual and environmental factors (Holgate, 2011). While exposures from multiple domains of the environment have been separately associated with asthma, no comprehensive measure capturing overall environmental quality, including air, water, land, built environment, and sociodemographics, has been examined in association with asthma. Examining asthma prevalence as a function of the many elements of environmental quality to which humans are simultaneously exposed can facilitate an understanding of how these complex exposures interact to affect asthma.

To explore the association between environmental quality and asthma prevalence, we linked the Environmental Quality Index (EQI) (Lobdell et al., 2014, 2011; Messer et al., 2014), a metric from the U.S. Environmental Protection Agency (US EPA), to the Truven Health MarketScan® Commercial Claims and Encounters Database (hereafter, MarketScan). The EQI integrates information from numerous variables across five environmental domains, enabling a more complete assessment of environmental quality and a better understanding of the role of environmental quality in health outcomes. The EQI has been used in prior studies of health outcomes including cancer incidence, mortality, pediatric multiple sclerosis, and preterm birth, and may also be useful in better understanding asthma (Jian et al., 2016; Rappazzo et al., 2015; Jagai et al., 2017; Lavery et al., 2017). The MarketScan database is a comprehensive source of individual-level, privately-insured medical claims; as such, MarketScan has data on millions more persons than would be covered in a survey, and is not subject to the same recall or non-response bias that occurs with self-reported surveys (Fowles et al., 1997, 1998; Ferver and Burton, 2009). We estimate the association between cumulative environmental quality and asthma among U.S. adults with health insurance plans captured in MarketScan; we further examine the association between individual environmental domains (air, water, land, built and sociodemographic environments) and asthma prevalence. Because health risk profiles differ in general between rural and urban areas in the U.S. Moy et al. (2017), and because asthma studies in particular have indicated mixed results in assessing rural-urban variations (Malik et al., 2012; Roy et al., 2010; Pesek et al., 2010; Son et al., 2015), we additionally explore heterogeneity by county-level rural-urban status.

2. Materials and methods

2.1. Exposure data

The Environmental Quality Index (EQI) is a summary measure constructed by the US EPA which incorporates five environmental domains (air, water, land, built, sociodemographic) into a single index representing the years 2000 – 2005 for all counties in the U.S. Data sources; construction of the EQI has been described elsewhere (Lobdell et al., 2011; Messer et al., 2014), and the data, along with an accompanying technical report, are publicly available (Lobdell et al., 2014). The air, water, and land domains were identified using the EPA's Report on the Environment (EPA, 2008); the built and sociodemographics domains were identified using the literature review and consultation with scientists (Lobdell et al., 2014). Then, 187 data sources across the five domains were evaluated to assess availability at the county level, availability for all 50 states, availability within the 2000–2005 time period, and data quality, which was assessed using reports by data source managers and project investigators, and through research papers that used and critiqued the data sources (Lobdell et al., 2011). Those which were retained for their data quality and availability at the county level for the entire U.S. enabled use of 219 unique variables across each of the five domains: air (87 variables), water (80), land (26), built (14), and sociodemographic (12) (Lobdell et al., 2011). An initial principal components analysis (PCA) produced five domain-specific indices, and a final PCA of the domain-specific indices produced the cumulative EQI.

Because of heterogeneity in environmental quality across the rural-urban continuum, the two-stage PCA process (domain-specific EQIs followed by cumulative EQI) was replicated within each of four rural-urban strata identified using U.S. rural-urban continuum codes (RUCCs) (Messer et al., 2014). RUCCs are a nine-part, county-level classification system defined by the United States Department of Agriculture, Economic Research Service (USDA, 2003; Hines et al., 1970). For the EQI, these nine categories were collapsed into four rural-urban strata: metropolitan-urbanized (original RUCC 1–3), non-metropolitan urbanized (original RUCC 4–5), less urbanized (original RUCC 6–7), and thinly populated (original RUCC 8–9). The use of these four categories is consistent with prior health studies (Luben et al., 2009; Messer et al., 2010; Langlois et al., 2010).

For our main exposure variable, we used quintiles of the EQI to compare higher quintiles (worse quality) to the lowest quintile (best quality). We conducted analyses using the cumulative EQI and the domain-specific indices across the entire U.S, and conducted stratified analyses within each RUCC to examine heterogeneity of effects by rural-urban status. For analyses using the domain-specific indices, all five indices were used in the same model so that associations could be examined in a multi-exposure context.