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Original Research

Spatial prevalence and associations among respiratory diseases in Maine

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ABSTRACT

Chronic respiratory diseases rank among the leading global disease burdens. Maine's respiratory disease prevalence exceeds the US average, despite limited urbanization/industrialization. To provide insight into potential etiologic factors among this unique, rural population, we analyzed the spatial distributions of, and potential associations among asthma, COPD, pneumonia, and URI adult outpatient data ($n = 47{,}099$) from all outpatient transactions ($n = 5{,}052{,}900$) in 2009 for Maine hospitals and affiliate clinics, using spatial scan statistic, geographic weighted regression (GWR), and a Delaunay graph algorithm. Non-random high prevalence regions were identified, the majority of which (84% of the population underlying all regions) exhibited clusters for all four respiratory diseases. GWR provided further evidence of spatial correlation ($R^2 = 0.991$) between the communicable and noncommunicable diseases under investigation, suggesting spatial interdependence in risk. Sensitivity analyses of known respiratory disease risks did not fully explain our results. Prospective epidemiology studies are needed to clarify all contributors to risk.

1. Introduction

Chronic respiratory diseases rank in the top 25 of diseases contributing to the world's global disease burden (Bousquet and Khaltaev, 2007). In the US, chronic obstructive pulmonary disease (COPD) is the 3rd highest cause of premature mortality (Brown et al., 2008; Ezzati et al., 2008), while asthma prevalence continues to increase in children and adults (Frampton et al., 2009; Shanawani, 2006). Spatial analyses of disease distribution in a physical environment often provide additional information on environmental risks. For example, studies of the consequences of ambient air pollution in urban settings investigated distance from roads or factories with known pollutants (Brunekreef et al., 2009; Pope et al., 2011; Jemal et al., 1975), and reported that prevalence of respiratory disease was highest in humans in closest proximity to the source (Lindgren et al., 2009; Nuvolone et al., 2011; Morris and Munasinghe, 1994). Within individuals, communicable and non-communicable respiratory diseases may not be independent of each other. For example, COPD is a risk factor for lung cancer while pneumonia appears to protect against lung cancer risk (Gao et al., 2009). These diseases, which appear to represent internecine risks to each other, contribute significantly to healthcare costs, and can be prevented or mitigated if diagnosed at an early stage.

Maine is a representative rural state with a slightly higher mortality rate attributed to respiratory diseases (52.3/100,00) compared to the US rate (43.2/100,000); and with significantly higher prevalence rates of asthma and COPD compared to most other US states (CDC, 2008;

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Report MaMW, 2012; Trends in asthma morbidity and mortality, 2012). Maine's prevalence of respiratory diseases varies geographically by county (Deprez et al., 2010). Although useful, county level resolution of quantitative data may obscure geographic clustering of diseases. Over the past 3 decades, Maine has mitigated or reversed health risks of environmental exposures associated with industries such as ship building, tanneries, and pulp and paper mills, or with specialty crop farming, such as aquaculture, potatoes and blueberries. In the northern two-thirds of Maine, the single major highway, Interstate 95, carries relatively little traffic (I-95 Corridor Facts [http://www.i95coalition.org/i95/Home/I95CorridorFacts/tabid/173/Default.aspx]), so exposure to diesel fumes is much less in the northern regions of the state than in the more urban settings of the south. There is a well-protected environment of forests, mountains and lakes throughout the state (Spills and Sites Cleanup [http://www.maine.gov/dep/spills/index.html]). A recent study by the American Lung Association showed Bangor, Maine to be among the cleanest cities in the US for year-round particle pollution and short-term particle pollution (Billings et al., 2011). The fraction of population in poverty (13.1%) places Maine at or just below the median for states in the US (Renwick, 2011; Short, 2010). Despite this apparently low health risk natural environment, Maine reports some of the highest rates of respiratory disease in the US, specifically chronic obstructive pulmonary disease (COPD) and lung cancer (CDC, 2010a,b), suggesting that other hazards contribute to risk (Holt et al., 2011). Using Maine state-wide health and environmental data, our aim was to apply spatial analyses to investigate spatial prevalence of selected communicable and non-communicable respiratory diseases and their potential associations with each other, and to assess if smoking, health insurance status, or rurality contribute to the prevalence of these respiratory diseases.

2. Methods

2.1. Data and data sources

This study was reviewed and approved by Eastern Maine Medical Center (EMMC) Internal Review Board and the United States Army Medical Research and Materiel Command (USAMRMC) Office of Human Protection (OHP) Human Research Protections Office (HRPO). Data sets were obtained under an agreement with the Maine Health Data Organization (MHDO), a state agency that collects health care data and makes those data available to researchers, policy makers, and the public while protecting individual privacy. By law, Maine hospitals and their provider-based clinics must submit case data to MHDO. Although there are legal exemptions, including the Department of Veterans' Affairs and employers operating their own health scheme for retired employees, if these patients request care at Maine's hospital and clinics, their record will be entered in the MHDO database. We obtained all MHDO outpatient records for hospitals and provider-based clinics in Maine in 2009 (n = 5,052,900), and excluded out-of-state outpatient records (n = 171,883). Data elements used from these records were: ICD-9-coded principal diagnosis, ZIP code of outpatient residence (the best available spatial resolution provided by MHDO), age at diagnosis, sex, race, ethnicity, and health insurance status. All transactions (records of data related to outpatient events) with a diagnosis of the non-communicable respiratory diseases, asthma and COPD (comprising chronic bronchitis and emphysema), and the communicable respiratory diseases, pneumonia and upper respiratory infection (URI), were extracted from the dataset (n = 99,340). We identified cases (n = 72,293) by removing duplicate transactions relative to the fields: medical record number and respiratory disease diagnosis. Finally, we excluded records of cases under 20 years of age (n = 25,194), resulting in 47,099 unique asthma, COPD, pneumonia, and URI cases for adult outpatients in Maine in 2009 for our analyses (see Table 1 for a summary). Based on outpatient ZIP code of residence, we aggregated outpatient counts for each Maine ZIP code by disease, gender, health insurance status, and age category.

We used the US Census 2010 SF3 file (American FactFinder, 2010), with population counts for ZIP code tabulation areas (ZCTAs), geographic representations of the US Postal Service ZIP code service areas, by age category and gender to perform spatial analyses. Age was grouped into 9 categories: 20–24, 25–34, 35–44, 45–54, 55–59, 60–64, 65–74, 75–84, and 85+; data analyses were age-adjusted. 422 ZCTAs were used in this study, each contained in one or more incorporated townships, and each with a non-zero population in the 2010 US Census. These ZCTAs account for 1,265,307 people of the total 1,328,361 population count in Maine in 2010, or 95% of the population. Based on outpatient ZIP code of residence, we aggregated outpatient counts for each Maine ZCTA by disease, gender, health insurance status, and age category. The ability to evaluate the contribution of race or ethnicity to risk or disease prevalence is limited as Maine is predominantly white (State and County QuickFacts, 2010). For this reason, we restricted our spatial analyses of respiratory disease trends to white Maine residents, excluding non-white cases and cases of unknown racial classification.

Supporting GIS data for this study includes: feature class *Roads*, from which Interstate 95 was extracted; *North America* demarcating state boundaries with neighboring states, Canadian provinces, and the Atlantic Ocean; feature class *Mountains*, representing the mountainous regions of Maine; and feature class *ZIP code* demarcating 2009 ZCTAs at 1:100,000 scale, including the latitude and longitude of each ZCTA's centroid (Fig. 1). The lattermost feature class is used to generate a locator reference file to geocode the outpatient data and also serves as the base point set – the ZCTA centroids – upon which spatial analysis was conducted. Since the use of ZCTAs in place of ZIP codes can potentially lead to spatial misalignment, and subsequently, quantitative and topological error in spatial analysis (Krieger et al., 2002), we took steps to mitigate such errors by processing the source ZCTA feature class (n = 940), as recommended in Grubesic and Matisziw (2006), including: removal of all water features (n = 292) and land masses without associated postal addresses (n = 70); and dissolving each set of polygonal regions with a common ZCTA to a single record, resulting in the final ZCTA feature class