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Research article

The modifying effect of socioeconomic status on the relationship between traffic, air pollution and respiratory health in elementary schoolchildren

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A B S T R A C T

The volume and type of traffic and exposure to air pollution have been found to be associated with respiratory health, but few studies have considered the interaction with socioeconomic status at the household level. We investigated the relationships of respiratory health related to traffic type, traffic volume, and air pollution, stratifying by socioeconomic status, based on household income and education, in 3591 schoolchildren in Windsor, Canada. Interquartile range changes in traffic exposure and pollutant levels were linked to respiratory symptoms and objective measures of lung function using generalised linear models for three levels of income and education. In 95% of the relationships among all cases, the odds ratios for reported respiratory symptoms (a decrease in measured lung function), based on an interquartile range change in traffic exposure or pollutant, were greater in the lower income/education groups than the higher, although the odds ratios were in most cases not significant. However, in up to 62% of the cases, the differences between high and low socioeconomic groups were statistically significant, thus indicating socioeconomic status (SES) as a significant effect modifier. Our findings indicate that children from lower socioeconomic households have a higher risk of specific respiratory health problems (chest congestion, wheezing) due to traffic volume and air pollution exposure.

1. Introduction

Urban air pollution exposure is associated with increased respiratory health effects (Brugha and Grigg, 2014). Traffic-related air pollution specifically has been linked to adverse respiratory health outcomes, and living near major roadways is associated with increased respiratory illness (Kim et al., 2004; Urman et al., 2014).

The city of Windsor, Ontario, is located on the USA-Canada border with the Ambassador Bridge linking the cities of Detroit and Windsor. It is the busiest international crossing between the two countries, and residents are affected by trans-boundary air quality issues due to the high density of traffic crossing from large trucks, cars, and commercial vehicles. A land use regression (LUR) study (Wheeler et al., 2008) to predict seasonal multiple-source pollutant concentrations of NO_2, SO_2 and volatile organic compounds indicated that concentrations increased in the city with proximity to the international border, with strong inter-pollutant correlations. These LUR models were applied in later studies to assess chronic air pollution exposure in schoolchildren (Cakmak et al., 2012; Dales et al., 2009, 2008).

Children are also more vulnerable to the negative health effects of ambient air pollution exposure (e.g., Confalonieri et al., 2007; Islam et al., 2007; Kovats and Hajat, 2008; O'Neill and Ebi, 2009). An increased breathing rate relative to body size, and an underdeveloped respiratory tract results in this heightened sensitivity, which also acts in combination with the harmful effects of high temperature (Karl et al., 2009). Many recent studies have examined the relationship between air quality and asthma in children (e.g., Barnett et al., 2005; Liu et al., 2009; To et al., 2013; Weinmayr et al., 2010), as asthma is a serious health and widespread chronic disease among children (Bryant-Stephens, 2009).

Abbreviations: NO_2, Nitrogen dioxide; part per billion (ppb), SO_2; sulphur dioxide, part per billion (ppb); $PM_{2.5}$, Particulate matter with a median aerodynamic diameter less than or equal to 2.5 μm.

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Air pollution exposure can also interact with socio-economic factors (Burra et al., 2009), for example, living in communities with lower household income and education levels has been shown to be associated with increased vulnerability to air pollution (Cakmak et al., 2007). Increased mortality in Hamilton, Ontario was associated with air pollution exposure, with low educational attainment and high manufacturing employment positively modifying the association, thus representing a proxy for poorer socioeconomic conditions (Jerrett et al., 2004). However, questions surrounding modifying effects of education and income that are linked to air pollution exposure are largely unanswered in the field and a closer look at household level, rather than neighbourhood level, analysis is required to tease apart influential variables. Traffic density, socioeconomic status, and air pollution are associated with increases in mortality and respiratory illness, and living near major roadways is related to increases in respiratory illness and asthma in children (Dockery, 2002; McConnell et al., 2006). Concerns regarding the disparities in air pollution exposure among differing socioeconomic groups are an important focus of the environmental justice movement. For example, Foster and Fostert (1998) and Grineski et al. (2007) found that controlling for socioeconomics, indoor hazards, and industry allowed for the identification of ozone as the strongest predictor of asthma hospitalizations in Phoenix, Arizona. In Hamilton, Ontario, Buzzelli and Jerrett (2003) found that large differences appeared in relation to changing industrial structure, which were similar to results in the United States (Clark et al., 2014; Grineski et al., 2007; Pope, 2014). These findings and others indicate a continental, intra-urban environmental injustice as experienced by low income, vulnerable populations from exposure to higher levels of air pollution (Buzzelli and Jerrett, 2003).

In this study, we linked information concerning both local roadways and air pollution to respiratory health among elementary school children in Windsor, Canada. We used land use regression to derive estimates of pollutant exposures resolved to the level of each subject's postal code, and traffic density parameters, as these can better capture the complex nature of traffic pollution than can a single pollution measurement (Cakmak et al., 2012). From this, we used a cross-sectional analysis to test the hypothesis that indicators of socioeconomic status, such as income and education, modify the respiratory health effects of gaseous and particulate air pollution, as well as the effect of roadway or traffic density on children's respiratory health.

2. Methods

2.1. Study population

As in Cakmak et al. (2012), the study included children with and without asthma in grades 4–6 in the Windsor public school system. An estimated 7200 children were approached for inclusion in 2005, with 2328 participating. Family socio-economic status and medical history information were collected from the Windsor Children's Respiratory Health Study questionnaires (Dales et al., 2009). Participation was not mandatory and approval was obtained from the Research Ethics Committee of Health Canada. The parents of the children reported on whether their child had a respiratory infection in the past week, their place of residence, postal code, child asthma medication use, smoking in the home, and the presence of pets.

2.2. Exposure to traffic

The volume and type of traffic were collected for roadways in the vicinity of the subject's home in 2005 by a trained observer using an electronic counter within the city of Windsor's Public Works Department and Geomatics Division. See Cakmak et al. (2012) for a detailed description. The Turning Movement Count (TMC) is the volume of traffic on a roadway segment, separated into two time intervals: 0700–1000 h, 0700–1800 h, and by all vehicles or truck only. Totals were counted for both vehicles and large trucks. The counts were determined by the volume and direction of traffic entering or leaving the segment of roadway at adjacent intersections.

The distance of the child's home to various types of roadways was determined by creating a 200 m radius around each child's postal code address, centered on the given postal code, which has a resolution of approximately 30 detached homes on the same side of the street or one apartment building. This radius was chosen as traffic-related pollutants (i.e., nitrogen oxides, carbon monoxide, volatile organic compounds) peak close to roadways and fall to background levels approximately 200 m from the pollutant source (Gilbert et al., 2003). Exposure to traffic-related air pollution was calculated as the sum of the traffic counts on all roadways within this boundary.

2.3. Air pollution

Yearly city-wide levels of air pollution for 2005 were estimated by averaging measurements from two fixed monitors within the city for hourly fine particulate matter ($PM_{2.5}$, $\mu m\ m^{-3}$), nitrogen dioxide (NO_2, ppb), and sulphur dioxide (SO_2, ppb), obtained from Environment Canada's National Air Pollution Monitoring System (NAPS) and resolved to the participant's neighborhood using a land use regression model (see Dales et al., 2008 for a full description of the method). The model was developed using road network data, population and dwelling counts, industrial point sources, distance to the Ambassador Bridge, and population density.

2.4. Lung function

As detailed in Cakmak et al. (2012): shortly after the administration of the questionnaire in 2005, pulmonary function testing was performed once for each child at the school by certified respiratory health therapists using KoKo Spirometers™ (Ferraris CardioRespiratory, Pulmonary Data Services Inc., Louisville, CO), with the results adjusted for temperature, barometric pressure, age, height, and gender (Polgar and Promadhat, 1971). A maximum of eight FVC maneuvers were carried out in an attempt to achieve three acceptable flow-volume loops, with two being within 200 mL for FVC and FEV1. The value assigned to the participant was the largest acceptable value within 200 mL of a second value. Increased exhaled nitric oxide (eNO) was measured prior to spirometry with single-breath-on-line measures of eNO with an Eco Physics CLD AL MED chemiluminescence analyzer (Eco Medics AG, Duernten, Switzerland).

2.5. Respiratory symptoms

Respiratory symptoms were self-reported in response to the following questions: “Does he/she usually have a cough apart from colds?,” “Does this child's chest ever sound wheezy or whistling?,” “Has this child ever had an attack of wheezing that has caused him/her to be short of breath?,” “Within the past year has this child had a chest illness that kept him or her at home for three consecutive days or more?” and “Has a physician ever told you this child had asthma, and does he or she still have it?” Statistical analyses were completed for each symptom alone (Cold Cough, Asthma, Wheeze with Dyspnoea, Wheeze, Chest Congestion, Chest Illness), as well as for any occurrence of respiratory symptoms other than those mentioned.