Original Contribution

GIS-Modeled Indicators of Traffic-Related Air Pollutants and Adverse Pulmonary Health Among Children in El Paso, Texas

Erik R. Svendsen, Melissa Gonzales, Shaibal Mukerjee, Luther Smith, Mary Ross, Debra Walsh, Scott Rhoney, Gina Andrews, Halûk Özkaynak, and Lucas M. Neas*

* Correspondence to Dr. Lucas M. Neas, Office of Research and Development, Environmental Protection Agency, MD-58A, Research Triangle Park, NC 27711 (e-mail: Neas.Lucas@epamail.epa.gov).

Investigators examined 5,654 children enrolled in the El Paso, Texas, public school district by questionnaire in 2001. Exposure measurements were first collected in the late fall of 1999. School-level and residence-level exposures to traffic-related air pollutants were estimated using a land use regression model. For 1,529 children with spirometry, overall geographic information system (GIS)-modeled residential levels of traffic-related ambient air pollution (calibrated to a 10-ppb increment in nitrogen dioxide levels) were associated with a 2.4% decrement in forced vital capacity (95% confidence interval (CI): –4.0, –0.7) after adjustment for demographic, anthropomorphic, and socioeconomic factors and spirometer/technician effects. After adjustment for these potential covariates, overall GIS-modeled residential levels of traffic-related ambient air pollution (calibrated to a 10-ppb increment in nitrogen dioxide levels) were associated with pulmonary function levels below 85% of those predicted for both forced vital capacity (odds ratio (OR) = 3.10, 95% CI: 1.65, 5.78) and forced expiratory volume in 1 second (OR = 2.35, 95% CI: 1.38, 4.01). For children attending schools at elevations above 1,170 m, a 10-ppb increment in modeled nitrogen dioxide levels was associated with current asthma (OR = 1.56, 95% CI: 1.08, 2.50) after adjustment for demographic, socioeconomic, and parental factors and random school effects. These results are consistent with previous studies in Europe and California that found adverse health outcomes in children associated with modeled traffic-related air pollutants.

air pollution; asthma; child; motor vehicles; nitrogen dioxide; vehicle emissions

Motor vehicles emit nitrogen dioxide and uncombusted fuel vapors into the atmosphere (1–3). These and other traffic-related air pollutants, often indexed by proximity to roadways, have been associated with adverse reproductive outcomes (4–8), childhood cancers (9–12), and adult mortality (13–18). Growing evidence suggests similar associations with allergies and asthma (19–30). However, relatively few studies have focused on traffic-related air pollution health effects within intra-urban exposure gradients.

Epidemiologic studies of intra-urban gradients of traffic-related air pollutant levels have been limited to Europe (20, 31–33), where there is much more extensive use of diesel vehicles, and Southern California (34–37), where pollutant levels are much higher than in most US cities. For a more general US risk assessment, additional studies of communities with vehicle fleets similar to those of the United States and air pollutant levels near or below the current National Ambient Air Quality Standards are needed.

We examined the association of ambient exposures to traffic-related air pollutants with children's respiratory health, as assessed by questionnaire and spirometry, in a predominantly Hispanic community along the United States/Mexico border. At the time of the study, El Paso, Texas, had a vehicle fleet similar to that of the rest of the United States and ambient air pollutant levels below or only slightly above the National Ambient Air Quality

Standards. We assessed exposures to traffic-related air pollutants at each child's school and current residence with a land use regression (LUR) model (38) that combined a geographic information system (GIS) with ambient passive monitoring throughout the city.

MATERIALS AND METHODS

Study location

El Paso is located in western Texas immediately north of the Rio Grande from Ciudad Juárez, Mexico. In the 2000 US Census, the population of El Paso was 563,662 (39), with another 1.2 million people living in Ciudad Juárez (40). Two major highways run through El Paso, with 3 major vehicular ports of entry along the border. Like many western US cities, it is topographically diverse. We divided the 54 public elementary schools into 2 areas by using a 1,170-m topographic contour: 20 "valley schools" in the El Paso and Mesilla valleys and 34 "upland schools" on the Hueco Bolson Plateau and in the western foothills of the Franklin Mountains. El Paso children generally attend the school closest to their residence and spend much of their time at home or at school. Therefore, we used both school- and residence-based exposure estimates separately to represent the maximum exposure duration of either.

Exposure assessment

In El Paso, the late fall and winter typically have higher pollutant levels and more stable spatial concentration gradients (41, 42). In February 1999, we conducted a pilot study of the winter peak air pollution season that found a 4-fold spatial gradient in ambient nitrogen dioxide levels across the El Paso area (43). Therefore, for two 1-week monitoring periods between November 28 and December 18, 1999, we established a more extensive passive monitoring network that measured levels of nitrogen dioxide (in parts per billion (ppb) (1 ppb nitrogen dioxide = 1.88 μg/m^3 at 25° C); an indicator of traffic and other combustion sources only) and selected volatile organic compounds (in μg/m^3; an indicator of traffic, other combustion sources, petroleum, and solvents) at 22 schools. We have discussed the sampling method, chemical analyses (44, 45), and LUR modeling elsewhere (46). The LUR predictions were successfully validated against measurements taken at 2 sites whose data were not used to develop the prediction equations (46). For this paper, we have focused on nitrogen dioxide and 6 gasoline-/diesel-related compounds: benzene, toluene, ethylbenzene, orthoxylene, metaxylene, and paraxylene (44).

For each study location, we used a GIS to calculate elevation, distance to the nearest international border crossing, distance to the nearest petroleum facility, population density and housing density of the census tract and 4 different buffer distances, distance to the nearest roadway according to 18 different categories of traffic volume, and traffic intensity within 6 different buffer distances. We then developed predictive GIS-based generalized additive models for selected pollutants. We used nonparametric smoothing functions to model population density and the distances to

border crossings and petroleum facilities and used linear functions for elevation, traffic volume, and traffic intensity. The final prediction models included elevation, distance to the nearest border crossing, distance to the nearest petroleum facility, population density of the census tract, distance to the nearest roadway with a traffic volume greater than 90,000 vehicles per day, and traffic intensity within 1,000 m (46). These LUR models were very predictive of the measured levels of nitrogen dioxide (coefficient of determination $(r^2) = 0.97$) and toluene $(r^2 = 0.93)$ and were used to provide GIS-modeled estimates at both the school (school-level estimate) and the current residence (residential-level estimate) for each child. (See Smith et al. (43) for detailed discussion of this regression method and results.)

Cohort attrition

In February 2001, the parents of all fourth- and fifth-grade El Paso public schoolchildren received a questionnaire packet which included both an English- and a Spanish-language questionnaire, a letter of introduction from the Superintendent of Schools, and a pencil inscribed with the study's toll-free telephone number (Figure 1). Teachers had instructed the children to take the questionnaire packet home to their parent/guardian and to return the completed questionnaire to school sealed in the packet. Each classroom received a small, nonmonetary incentive for the achievement of an 85% return of the questionnaire. After 2 weeks, 84% of the questionnaires were returned; 5% of these indicated a refusal to participate. We excluded children with a positive report or missing information regarding serious health conditions unrelated to the principal focus of this study (cystic fibrosis, heart disease, chest operation, serious chest injury, or neonatal oxygen), missing information on model covariates, and missing data on key symptoms or conditions. Subsequent respiratory symptom analyses were based on questionnaire information for 5,654 children.

During March 2001 through May 2001, we performed pulmonary function examinations on only the children from the 22 schools in the air monitoring study (Figure 1). We examined only children with explicit written permission from a parent/guardian and obtained their informed assent prior to examination, which was conducted at their school during school hours with a school nurse on site. Each child received a small, nonmonetary incentive for their appearance at the examination room, regardless of the acceptability and reproducibility of their examination. We measured each child's weight and standing height prior to examination. Each child was asked 3 screening questions: whether they had ever smoked more than 5 cigarettes in their lifetime, whether they had recently had a respiratory infection, and whether they were willing to perform the pulmonary function maneuver. All children who had smoked more than 5 cigarettes, had had a recent respiratory infection, or were unwilling to perform the maneuver were excluded. We excluded children who were excluded from the respiratory health cohort and children with missing data on model covariates, extreme heights or weights (<120 cm or >160 cm, <22.7 kg or >68.1 kg), and inadequate spirometry performance based on contemporaneous technician reports and an independent
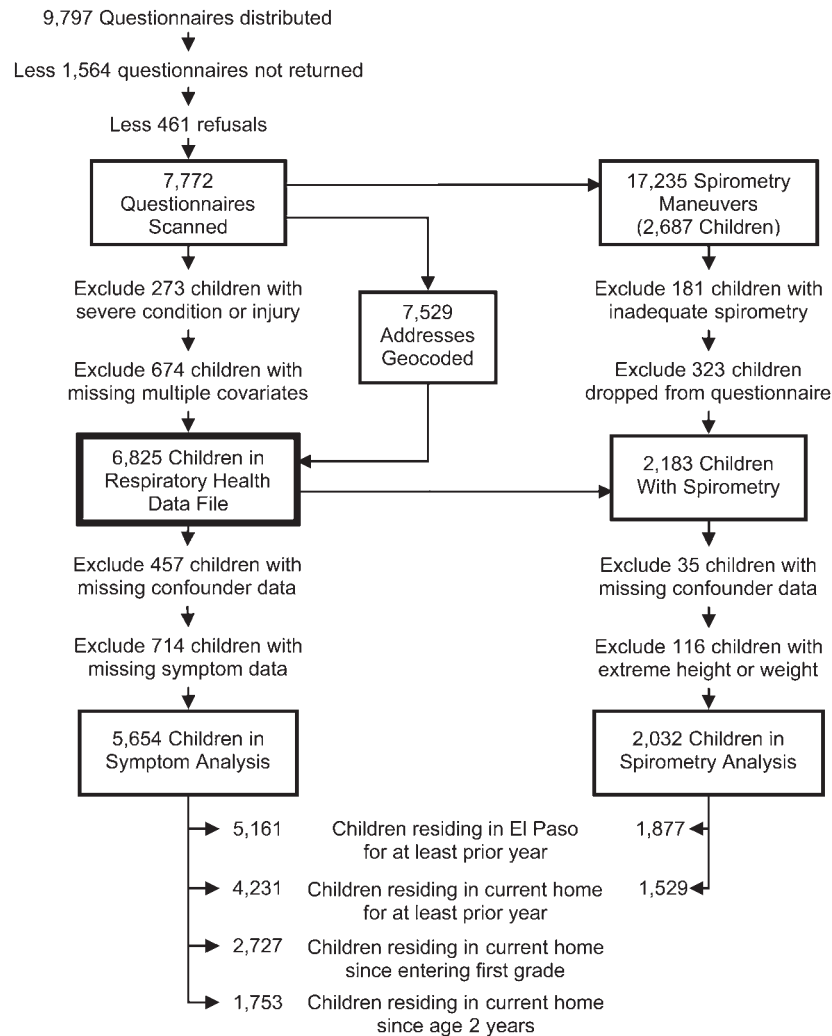
Figure 1. Attrition of the El Paso Children's Health Study cohort from the target population of all fourth- and fifth-grade public schoolchildren, El Paso, Texas, February 2001.

review of each spirometry tracing. Subsequent spirometry analyses were based on information for 2,032 children (3,622 children were excluded from the 32 schools not included in the air monitoring study).

Duration of residence

The principal analyses focused on children who had lived at their current residence for at least 1 year prior to the questionnaire distribution (26): 4,231 children for the respiratory symptom analyses and 1,529 for the spirometry analyses (Figure 1).

Respiratory health questionnaire

The respiratory health questionnaire was based on the American Thoracic Society children's questionnaire (47),

which was successfully used in studies of regional air quality gradients (48, 49) and an intra-urban air quality gradient (50). No physical activity or exercise data were gathered. The Spanish-language translation (51) was reviewed and modified by native Spanish-speaking epidemiologists from the US Environmental Protection Agency (EPA) and the Mexican Ministry of Health (Salúd Mexico) to more closely represent the Spanish used in the El Paso/Ciudad Juárez border region. The Spanish-language questionnaire was further reviewed by Spanish-speaking staff at the EPA's El Paso field office and field-tested among parents in El Paso. Both the English and Spanish questionnaires were reviewed and approved by the White House Office of Management and Budget, the Biomedical Institutional Review Board of the University of North Carolina, and the EPA's Human Research Subjects Protection Officer.

Spirometry

We followed the American Thoracic Society recommendations for spirometry (52). The examination was halted after 3 maneuvers that met American Thoracic Society criteria for acceptability and reproducibility, after 8 attempts to perform the maneuver, or upon request of the child.

Statistical analysis

The logistic models adjusted for random school effects; a fixed design effect for use of the Spanish-language questionnaire; an indicator for valley schools; and fixed covariate effects for sex, age, race (4 categories), Hispanic ethnicity, parental education (4 categories), parental allergies, the presence of a gas stove with a pilot light in the home, and secondhand exposure to tobacco smoke in the home. The potentially confounding effect of these covariates was assessed in comparison with a simplified model that included only 3 design factors: random school effects, a fixed design effect for the Spanish-language questionnaire, and an indicator for valley schools.

As in a similar study (53), pulmonary function was modeled as the natural logarithm of each measure adjusted for random spirometers/technician effects; an indicator for valley schools; and fixed covariate effects for sex, age, race (4 categories), Hispanic ethnicity, parental education (4 categories), secondhand smoke in the home, the natural logarithms of height and weight, an interaction between sex and height, and interactions between Hispanic ethnicity and height and weight.

Internal reference values for each pulmonary function measure were calculated for each child from predictive models based on sex, age, race (4 categories), Hispanic ethnicity, parental education (4 categories), secondhand smoke in the home, the natural logarithms of height and weight, an interaction between sex and height, and interactions between Hispanic ethnicity and sex, height, weight, and the sex-height interaction. As in a similar study (53), a binary indicator of low pulmonary function was then constructed using arbitrary cutpoints selected to achieve an approximate 8%–10% prevalence of low values for each parameter: 85% of the predicted value for forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1) and 80% of the predicted value for peak expiratory flow.

RESULTS

Cohort characteristics

Approximately 62% of the children attended the upland schools and 38% the valley schools. While child's age, sex, and reported race varied little between the valley and upland schools, we observed higher prevalences in the valley schools of 6 potential confounders: Hispanic ethnicity, use of the Spanish-language questionnaire, lower parental educational levels, single-parent families, secondhand smoke in the home, and the presence of a gas cooking stove with a pilot light (Table 1). The prevalence of parental allergies was also lower in valley schools.

Table 1. Characteristics of 4,231 Public Schoolchildren in a Study of Exposure to Traffic-related Air Pollutants and Children's Pulmonary Health, by School Elevation, El Paso, Texas, February 2001

|	Valley Schools (Elevation ≤1,170 m)		Upland Schools (Elevation >1,170 m)	
	No.	%	No.	%
No. of schools	20		34	
No. of participants[a]	1,627		2,604	
Female sex		53		51
Race				
White		74		72
Black		1		6
Other, specified		3		5
Hispanic who skipped racial identification		22		16
Hispanic		91		76
Spanish-language questionnaire		46		25
Parental education				
Less than high school graduate		26		11
High school graduate		23		18
Some postsecondary education		23		23
College graduate		28		48
Single-parent family		33		26
Parental allergies		27		38
Gas cooking stove with a pilot light in the home		47		36
Secondhand exposure to tobacco smoke in the home		34		29

[a] The mean age of children in both valley schools and upland schools was 10.1 years.

Almost all (92%) of the questionnaires were completed by a biologic parent, usually the mother (78%). While we used standard questions to assess race and Hispanic ethnicity and we provided Spanish-language questionnaires to all potential respondents, 22% of the Hispanics skipped the racial identification question. This lack of racial identification was slightly higher on the Spanish-language questionnaire (28%) than on the English-language questionnaire (19%). Instead of attributing the missing racial identification values to a specified race, we created a binary indicator for non-racially identified Hispanics and treated this indicator as a distinct self-identified racial category.

GIS-modeled exposures

School-level GIS-modeled exposure estimates for nitrogen dioxide levels had a distribution similar to the measured levels (Figure 2). The elevation gap between 1,160 m and 1,180 m that separates the 20 valley schools and the 34 upland schools was evident (Figure 2). Figure 3 has a separate concentration scale for each pollutant, and the mean
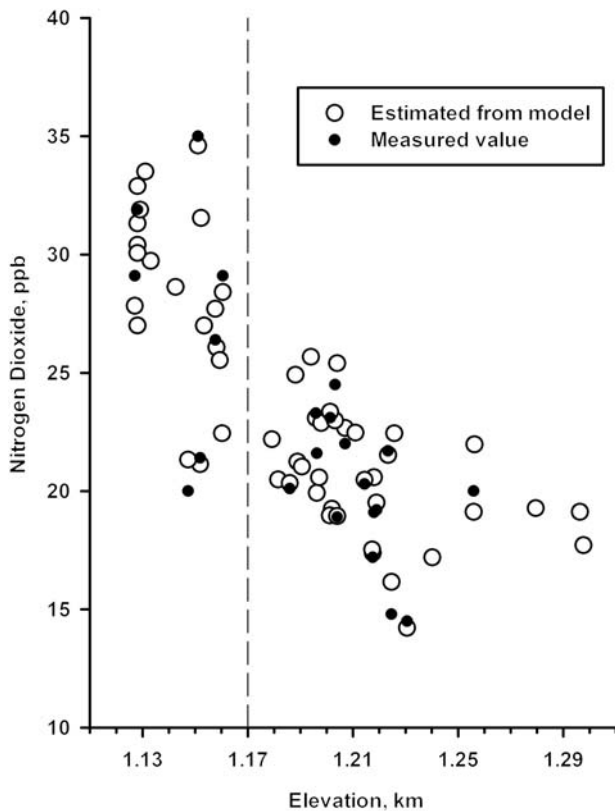
Figure 2. School-level estimates of land use regression-modeled traffic-related air pollutant levels (calibrated to a 10-ppb increment in nitrogen dioxide levels) for 54 public elementary schools, by school elevation, El Paso, Texas, November/December 1999.

concentration of nitrogen dioxide was approximately 8 times that of toluene.

Among the 4,231 children in these principal analyses, the residence-level estimates for nitrogen dioxide were highly correlated with the school-level estimates (Pearson's correlation coefficient $(r) = 0.90$) and with the residence-level exposures for toluene $(r = 0.93)$ and benzene $(r = 0.95)$. For the volatile organic compounds, the modeled residence-level exposures were all so highly intercorrelated $(r > 0.98)$ as to indicate no differences in their value as indicators of traffic-related air pollutants. For the children attending the 22 monitored schools, the GIS-modeled residence-level estimates for nitrogen dioxide were highly correlated with the school-level measurements of nitrogen dioxide $(r = 0.88)$ but were less correlated with the school-level measurements of toluene $(r = 0.77)$ and benzene $(r = 0.77)$.

Pulmonary function levels and GIS-modeled exposures

After adjustment for potential covariates, GIS-modeled residential estimates for ambient levels of traffic-related air pollutants (calibrated to a 10-ppb increment in nitrogen dioxide) were associated with a 2.4% lower FVC (95%

confidence interval (CI): −4.0, −0.7). The association of GIS-modeled exposures with FVC did not differ greatly by elevation category, but the pulmonary flow measures (FEV_1 and peak expiratory flow) were associated with GIS-modeled exposures only among children attending the upland schools (Table 2).

The percent decrement in FVC associated with a 10-ppb increment in GIS-modeled nitrogen dioxide levels increased with the stability of the child's recent residence (Figure 4). The association did not vary by sex, lifetime asthma status, or the presence of a gas cooking stove with a pilot light in the home, but it was much stronger in homes without secondhand smoke than in homes with smoking.

The GIS model calibrated with nitrogen dioxide measurements produced a stronger association with percent difference in FVC than GIS models calibrated with measurements of toluene, other volatile organic compounds, or fine particulate matter when the association for each pollutant was scaled equivalently to exactly twice the interquartile range for that pollutant (Figure 5). For nitrogen dioxide, no systematic differences in the estimated decrement in FVC were observed for exposure estimates based on measured school values (−2.8), modeled school estimates (−2.5), or modeled residence estimates (−2.7). For toluene, the apparent increase in the estimated decrement may be related to the increasing toluene-to-nitrogen dioxide correlation for the measured school values $(r^2 = 0.77)$, modeled school estimates $(r^2 = 0.83)$, and modeled residence estimates $(r^2 = 0.84)$.

After adjustment for potential covariates, overall GIS-modeled residential estimates for ambient levels of traffic-related air pollutants (calibrated to a 10-ppb increment in nitrogen dioxide) were associated with pulmonary function levels below 85% of those predicted for both FVC (odds ratio (OR) = 3.1, 95% CI: 1.65, 5.78) and FEV_1 (OR = 2.35, 95% CI: 1.38, 4.01). These associations were stronger among children attending the upland schools but were still significant among children attending the valley schools (Table 3).

Respiratory conditions and GIS-modeled exposures

Among children attending upland schools, modeled residential estimates for ambient levels of traffic-related air pollutants (calibrated to a 10-ppb increment in nitrogen dioxide) were associated with a physician's diagnosis of bronchitis in the last year (OR = 1.80, 95% CI: 1.10, 2.93) and current asthma (OR = 1.65, 95% CI: 1.08, 2.50), as indicated by a physician's diagnosis of asthma in the last year or the use of asthma medications in the last year (Table 4). Among the children attending valley schools, we found no associations with modeled exposures aside from protective associations with wheezing in the prior year and lifetime histories of either hay fever or a physician's diagnosis of allergies.

DISCUSSION

This study found a 2.4% decrement in children's FVCs associated with a 10-ppb increment in GIS-modeled
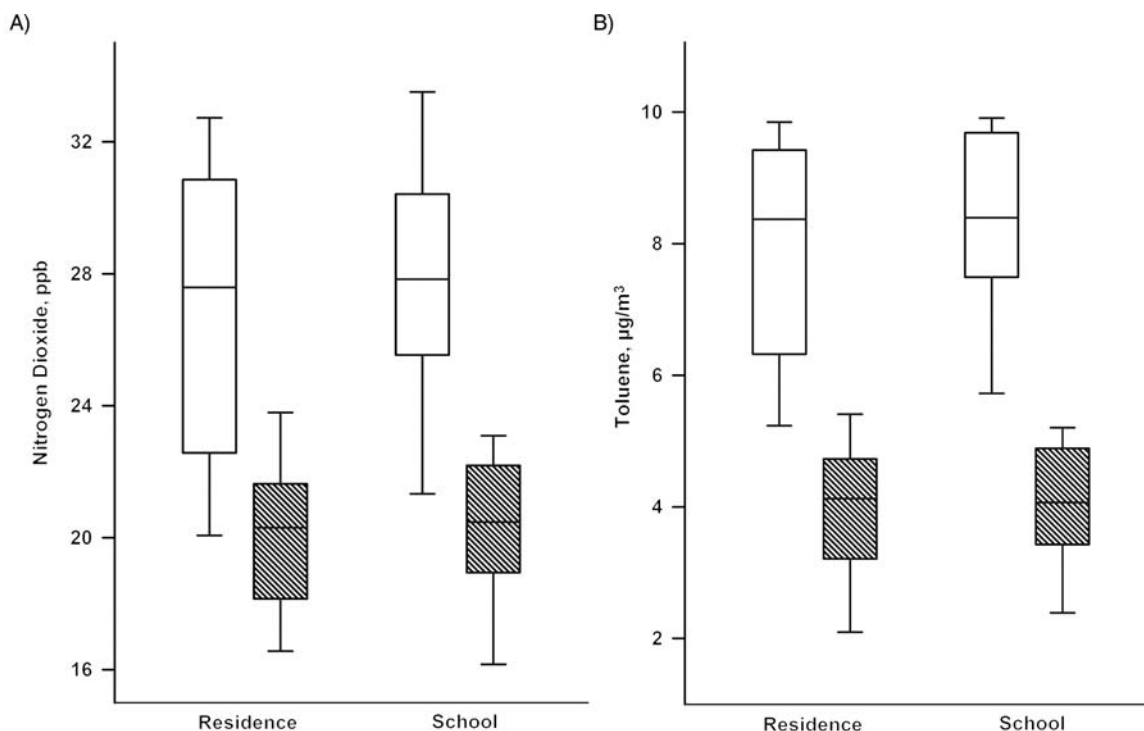
Figure 3. Residence- and school-level estimates of land use regression-modeled traffic-related air pollutant levels calibrated for nitrogen dioxide (left) and toluene (right), by school elevation category (empty boxes, valley schools; hatched boxes, upland schools), El Paso, Texas, February 2001. Results were based on air quality monitoring from November/December 1999. Bars, 95% confidence interval.

nitrogen dioxide levels that was similar for both valley and upland schools (Table 2). This association tended to strengthen with duration of residence in El Paso (Figure 4). When restated as a binary indicator of a level less than 85% of that predicted, we found that a 10-ppb increment in GIS-modeled nitrogen dioxide levels remained associated with lower FVC for the entire cohort (OR = 3.1), but the association was stronger for the upland schools (OR = 3.9) than for the valley schools (OR = 2.5) (Table 3). This valley-upland difference was even greater for respiratory

conditions, and only the upland schools showed a 10-ppb increment in GIS-modeled nitrogen dioxide levels associated with a higher prevalence of current asthma (OR = 1.7) and bronchitis (OR = 1.8) (Table 4). Finally, only the upland schools showed a 5.4% decrement in peak expiratory flow associated with a 10-ppb increment in GIS-modeled nitrogen dioxide (Table 2).

In this study, measurements of nitrogen dioxide or selected volatile organic compounds were used in a LUR model that combined information on proximity to line sources
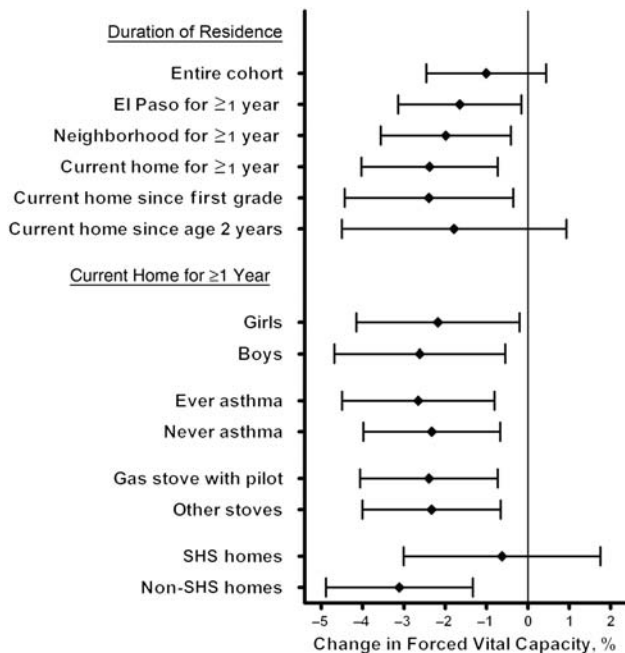
Table 2. Adjusted Percent Difference in Pulmonary Function Level According to LUR-modeled Traffic-related Air Pollutant Levels (Calibrated to a 10-ppb[a] Increment in Nitrogen Dioxide Levels) Among 1,529 Public Schoolchildren, by School Elevation, El Paso, Texas, February 2001

|	Valley Schools (Elevation ≤1,170 m)		Upland Schools (Elevation >1,170 m)	
	% Difference[b]	95% CI	% Difference	95% CI
Forced vital capacity	−2.4	−4.3, −0.5	−2.3	−4.7, 0.3
Forced expiratory volume in 1 second	−1.1	−3.2, 1.1	−2.7	−5.4, 0.0
Peak expiratory flow	0.1	−3.2, 3.4	−5.4	−9.3, −1.3

Abbreviations: CI, confidence interval; LUR, land use regression; ppb, parts per billion.

[a] 1 ppb nitrogen dioxide = 1.88 μg/m^3 at 25°C.

[b] Percent difference in pulmonary function level modeled as the natural logarithm of pulmonary function, adjusted for random spirometer/technician effects; fixed covariate effects for sex; race (4 categories); Hispanic ethnicity; the natural logarithms of age, height, and weight; interaction between sex and height; interactions between Hispanic ethnicity and sex, height, weight, and the sex-height interaction; parental education (4 categories); secondhand smoke in the home; and an indicator for school elevation (elevation-specific intercepts).

Figure 4. Adjusted percent difference in children's pulmonary function with land use regression-modeled traffic-related air pollutant levels calibrated to a 10-ppb increment in nitrogen dioxide levels, according to selected characteristics, El Paso, Texas, February 2001. Bars, 95% confidence interval. (SHS, secondhand smoke).
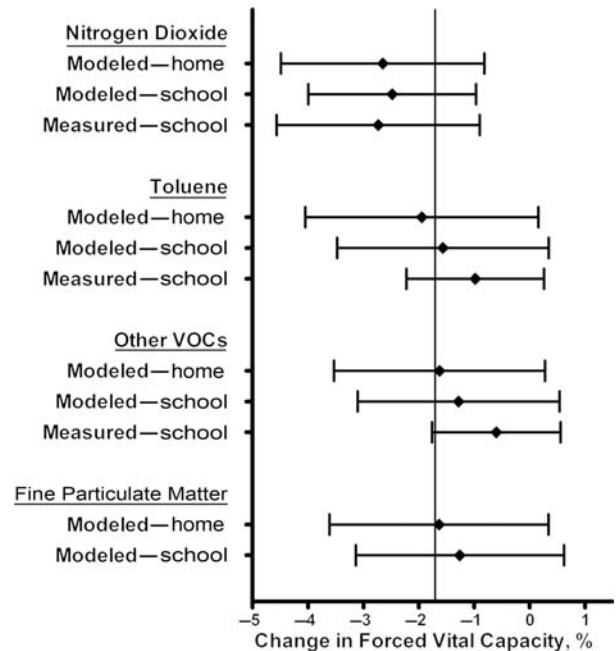
Figure 5. Adjusted percent difference in children's pulmonary function with a 2×interquartile-range increment in land use regression-modeled traffic-related air pollutant levels, by pollutant, El Paso, Texas, February 2001. "Other VOCs" represents the sum of other selected volatile organic compounds (VOCs): benzene, ethylbenzene, and ortho-, meta-, and paraxylene. Bars, 95% confidence interval.

(major roadways), area sources (local traffic), and point sources (major border crossings). School- and residential-level exposures for each child were estimated from these models. We did not consider alternative exposure models based on single GIS variables, but we relied solely on the best predictive model for each monitored pollutant. We examined possible effect modification by duration of residence as an indicator of exposure misclassification. We examined associations stratified by gender and by asthma status as major determinants of pulmonary function because effect modification by these variables has been reported for other health endpoints in previous studies of children and air pollutants (34, 54). We also examined effect modification by major indoor sources of personal exposure to nitrogen dioxide (gas stoves) and secondhand smoke (55, 56). Since our questionnaire lacked specific questions on physical activity, we were not able to examine possible effect modification by participation in outdoor activities as reported in an earlier study (54). This was a limitation of our study.

In a 2004 review of 34 epidemiologic studies of traffic-related pollutants and allergic disease (32), only 2 other studies used a similar approach to exposure assessment with LUR models (57, 58). In the 2 European studies, nitrogen dioxide measurements performed as well as fine particle measurements in the calibration of the regression models. The other reviewed studies relied on perceived exposures (8 studies), assignment to the nearest monitor (5 studies),

dispersion models (4 studies), residential monitoring (1 study), or single GIS indicators of proximity to the source (18 studies). Since 2004, there have been 2 additional studies which have used LUR modeling (20, 59). The use of nitrogen dioxide as an exposure metric in the LUR model should not be interpreted as a direct association with health. Nitrogen dioxide served as an indicator for all mobile source emissions, the primary source of ambient nitrogen dioxide in the El Paso area. The absence of effect modification by gas stoves, a major source of personal exposure to nitrogen dioxide, suggests a simple additive relation between indoor and ambient nitrogen dioxide, while the effect modification by secondhand smoke, a major source of personal exposure to respirable particles, suggests a more complex relation (Figure 4). Other indicators of mobile source emissions provided results congruent with those for nitrogen dioxide (Figure 5). The observed association with FVC in El Paso appeared stronger than the associations observed in the Southern California Children's Health Study (a study of 2,781 children in grades 4, 7, and 10) (60), an Italian study of 2,107 children in Rome (20), and a Canadian study of 2,328 children in Windsor, Ontario (59). In the Southern California study, a 25-ppb increment in nitrogen dioxide was associated with a 46-mL decrement in mean FVC across all subjects (34, 60). For the El Paso study, a 2.4% decrement in mean FVC of 2,575 mL for a 10-ppb increment in

Table 3.   Adjusted Odds Ratios for the Association of Low Pulmonary Function With LUR-modeled Traffic-related Air Pollutant Levels (Calibrated to a 10-ppb[a] Increment in Nitrogen Dioxide Levels) Among 1,484 Public Schoolchildren, by School Elevation, El Paso, Texas, February 2001

	Prevalence, %	Valley Schools (Elevation ≤1,170 m)		Upland Schools (Elevation >1,170 m)	
		Adjusted OR[b]	95% CI	Adjusted OR	95% CI
Forced vital capacity <85% of predicted[c]	7.5	2.50	1.06, 5.86	3.85	1.62, 9.10
Forced expiratory volume in 1 second <85% of predicted	8.8	2.03	1.01, 4.07	2.78	1.33, 5.78
Peak expiratory flow <80% of predicted	11.1	1.24	0.70, 2.22	1.45	0.72, 2.92

Abbreviations: CI, confidence interval; LUR, land use regression; OR, odds ratio; ppb, parts per billion.

[a] 1 ppb nitrogen dioxide = 1.88 µg/m^3 at 25°C.

[b] Adjusted for random school effects; a fixed design effect for use of the Spanish-language questionnaire; fixed covariate effects for sex, age, race (4 categories), Hispanic ethnicity, parental education (4 categories), parental allergies, the presence of a gas cooking stove with a pilot light in the home, and secondhand smoke in the home; and an indicator for school elevation (elevation-specific intercepts).

[c] Predicted values were obtained from an internal, regression-based estimate of the natural logarithm of pulmonary function with sex, age, race (4 categories), Hispanic ethnicity, the natural logarithms of height and weight, an interaction between sex and height, and interactions between Hispanic ethnicity and sex, height, weight, and the sex-height interaction.

nitrogen dioxide would suggest a 155-mL decrement for a 25-ppb increment in nitrogen dioxide. The small proportional shift in the distribution (2.4%) produces a more striking change in the proportion of children with an FVC less than 85% of that predicted (OR = 3.1).

The apparent valley-upland differences in the associations between exposure to traffic-related air pollutants and the various respiratory conditions may be related to a number of factors, including chance. Selection bias may have been present among children attending valley schools if parents of healthy children with higher residential mobility tended to reside in homes with higher exposures along major highways or near the border or, more likely, if parents of asthmatic children avoided such residences in the

Table 4.   Crude and Adjusted Odds Ratios for the Association of Selected Respiratory Symptoms With LUR-modeled Traffic-related Air Pollutant Levels (Calibrated to a 10-ppb[a] Increment in Nitrogen Dioxide Levels) Among 4,231 Public Schoolchildren, by School Elevation, El Paso, Texas, February 2001

	Symptom Prevalence, %	Valley Schools (Elevation ≤1,170 m)			Upland Schools (Elevation >1,170 m)		
		Crude OR[b]	Adjusted OR[c]	95% CI	Crude OR	Adjusted OR	95% CI
Lifetime symptom history							
Asthma (physician's diagnosis)	10.2	0.66	0.78	0.52, 1.16	1.30	1.31	0.87, 1.97
Allergy (physician's diagnosis)	30.7	0.67	0.74	0.57, 0.97	1.20	1.13	0.84, 1.53
Hay fever	15.2	0.50	0.60	0.40, 0.93	1.30	1.20	0.81, 1.76
Symptoms in the last year							
Use of asthma medication	7.2	0.66	0.78	0.49, 1.24	1.66	1.63	1.03, 2.59
Asthma (physician's diagnosis)	7.7	0.75	0.83	0.57, 1.20	1.39	1.34	0.89, 2.01
Asthma (diagnosis or medications)	9.2	0.74	0.81	0.55, 1.21	1.73	1.65	1.08, 2.50
Bronchitis (physician's diagnosis)	5.6	0.70	0.87	0.54, 1.40	1.74	1.80	1.10, 2.93
Hay fever (physician visit)	13.2	0.48	0.64	0.37, 1.12	1.37	1.31	0.80, 2.12
Symptoms apart from colds							
Wheezing	6.8	0.39	0.51	0.33, 0.79	1.20	1.45	0.97, 2.19
Chronic cough in the morning	3.4	0.79	0.91	0.50, 1.65	1.74	1.72	0.92, 3.21
Cough at other times	4.9	0.89	1.01	0.61, 1.70	1.80	1.67	0.99, 2.83

Abbreviations: CI, confidence interval; LUR, land use regression; OR, odds ratio; ppb, parts per billion.

[a] 1 ppb nitrogen dioxide = 1.88 µg/m^3 at 25°C.

[b] Adjusted for random school effects, a fixed design effect for use of the Spanish-language questionnaire, and an indicator for school elevation (elevation-specific intercepts).

[c] Adjusted for random school effects; a fixed design effect for use of the Spanish-language questionnaire; fixed covariate effects for sex, age, race (4 categories), Hispanic ethnicity, parental education (4 categories), parental allergies, the presence of a gas cooking stove with a pilot light in the home, and secondhand smoke in the home; and an indicator for school elevation (elevation-specific intercepts).

valley areas. Nondifferential exposure misclassification may have been greater among children attending the valley schools due to inadequacy of our LUR model. Children attending the valley schools also differed with regard to questionnaire language and parental education, and these factors may have led to misclassification of lung health symptoms. There may have been differences in access to medical care in the valley areas, which could explain the protective associations with physician-diagnosed disease.

Nevertheless, among the children attending the upland schools, we observed associations between GIS-modeled exposure to traffic-related air pollutants and both asthma and bronchitis in the last year. The association with a recent physician's diagnosis of asthma (OR = 1.3 for a 10-ppb increment in nitrogen dioxide) was strengthened by considering a recent diagnosis in combination with the use of asthma medications in the last year (OR = 1.7). Exposure to traffic-related air pollutants was more strongly associated with cough symptoms than with recent wheezing or a history of allergies or hay fever.

We found that increasing exposure to indicators of traffic-related air pollution was associated with significant decrements in lung function among El Paso schoolchildren. While not conclusive in themselves, these results are consistent with the findings of previous epidemiologic studies that have observed adverse respiratory health outcomes in children associated with proximity-to-source indicators of long-term exposures to traffic-related air pollutants.

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