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Outdoor air pollution, family and neighborhood environment, and asthma in LA FANS children

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Abstract

We examined associations between outdoor air pollution and childhood asthma, using measures of SES, neighborhood quality and social support from the Los Angeles Family and Neighborhood Survey (LA FANS). We linked residential census tracts for 3,114 children to government air monitoring stations and estimated average pollutant concentrations for the year before interview. CO and NO_2 levels increased and O_3 levels decreased as neighborhood quality decreased, yet correlations were low. Pollutant levels were not correlated with neighborhood support. Even after adjustment for social environment characteristics, LA FANS children living in high O_3, PM_{10}, and CO areas appeared to have worse asthma morbidity.

Keywords

air pollution; asthma; children; socioeconomic status; neighborhood

Background

Asthma is a complex, multifactorial disease. In addition to genetic propensity, aspects of both the social and physical environment are likely important in asthma causation and progression. Reports of higher asthma morbidity in low socioeconomic status (SES) neighborhoods might reflect the independent effects or the interplay between social and physical aspects of the community (Gold and Wright, 2005, Mielck et al., 1996). Outdoor air pollution is one physical neighborhood factor that can impact asthma, and there is evidence that economically disadvantaged neighborhoods are often more exposed to air pollution (O'Neill et al., 2003, Houston et al., 2004, Kohlhuber et al., 2006). It is generally well-established that short-term increases in outdoor air pollution can worsen respiratory symptoms in asthmatic children (Gilmour et al., 2006, Trasande and Thurston, 2005, Thurston and Bates, 2003, Brunekreef and Holgate, 2002). Ozone (O_3) and particulate matter less than 10 and 2.5 microns in aerodynamic diameter (PM_{10} and $PM_{2.5}$) are the pollutants most consistently linked with exacerbation of asthma symptoms. While long-term exposures to O_3, PM_{10} and nitrogen

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dioxide (NO_2) have been associated with chronic respiratory impairments such as reduced lung function and growth, bronchitis and chronic cough, data on asthma incidence are less conclusive (Gilmour et al., 2006, Trasande and Thurston, 2005, Brunekreef and Holgate, 2002). Recently, air pollution research has focused on the contributions of specific motor vehicle exhaust components such as polycyclic aromatic hydrocarbons (PAHs) sorbed to particles from diesel engines and ultrafine particles (less than 0.1 microns in aerodynamic diameter), which are more able to penetrate cellular targets in the lung and enter systemic circulation (Kunzli et al., 2003, Li et al., 2003, Li et al., 2002, Pandya et al., 2002). Various measures of traffic exhaust exposure have been associated with adverse respiratory outcomes including reduced lung function and growth, asthma hospitalizations, and prevalence of asthma, wheeze, bronchitis, and allergic rhinitis (Salam et al., 2008, Brauer et al., 2007, Bayer-Oglesby et al., 2006,Gauderman et al., 2007).

Low SES neighborhood impacts on asthma morbidity may also reflect differences in the social environment. For example, neighborhood factors, such as economic disadvantage, violence, low social cohesion, and low social capital may act through stress pathways to worsen asthma outcomes (Gold and Wright, 2005). Higher levels of psychosocial stress have been linked to greater morbidity in asthmatic children (Sandberg et al., 2004, Wright, 2005, Chen et al., 2006, Miller and Chen, 2006), and there is growing evidence from prospective studies that psychosocial stress may contribute to the development of wheezing illnesses and asthma, especially in early life (Gold and Wright, 2005, Wright et al., 2002, Wright et al., 2004). Other potentially important factors related to SES include differential access to health care and differences in health behaviors such as diet and smoking.

Thus, it has been argued that in order to adequately evaluate the contributions of the physical environment to health outcomes such as asthma, is important to consider social aspects as potential confounders and effect measure modifiers (O'Neill et al., 2003) . The first wave of The Los Angeles Family and Neighborhood Survey (LA FANS) collected extensive data on individual, family, and neighborhood characteristics of Los Angeles residents (Sastry et al., 2003), allowing us to evaluate associations between outdoor air pollution and asthma taking into account both physical and social aspects of neighborhoods. While most previous studies examining this issue relied solely on SES measures based on administrative data sources (such as census data) to reflect exposures to adverse social conditions, the LA FANS study collected information directly from participants regarding their ratings of neighborhood safety, cohesion and social support, providing us with additional measures of neighborhood social environment to consider in our analyses of outdoor air pollution’s impact on asthma.

Methods

Subjects

A multistage method was used to select LA FANS neighborhoods (defined as census tracts) and participants (Sastry et al., 2003). LA County census tracts were assigned to three SES strata based on the percentage of the tract population living below the poverty line. LA FANS subjects were then selected by stratified sampling first of census tracts, followed by census blocks, and then households. Very poor and poor tracts ($\geq 90^{th}$ percentile and between the 60–89th percentiles of the poverty distribution, respectively) and households with children were over-sampled. Within each household, one adult (≥18 years) and one child (<18 years) were randomly selected for interview. Only children aged ≥9 years were directly interviewed. The primary caregiver of the randomly selected child (usually the child’s mother) was also interviewed about the child (regardless of the child’s age) and if the child had one or more siblings with the same biological or adoptive mother and the same primary caregiver, one sibling was also randomly selected for interview. LA FANS Wave One interviews were conducted between April 2000 and January 2002, and included 3,090 households in 65 census tracts, with 30%, 31% and 39% of the households in the very poor, poor and non-poor strata, respectively. The following analyses included 3,114 children (ages 0–17 years) with data on the health outcomes of interest and census tract of residence.

Outcome Assessment

Each child's primary caregiver (PCG) was interviewed about the child's health status, including the presence of asthma. Specifically, the PCGs were asked "Has a doctor or other health professional ever told you that [child's name] has asthma?". Those who responded 'yes' were also asked "During the past 12 months has [child's name] had an episode of asthma or an asthma attack?". The responses to these questions were used to define children as asthmatics with attacks in the previous 12 months, asthmatics without attacks in the previous 12 months, or nonasthmatics.

Exposure Assessment

Exposure to outdoor air pollution was assessed based on measurements collected by the South Coast Air Quality Management District (SCAQMD) at a network of air monitoring stations located throughout the county, using methods similar to those employed in our previous studies (Ritz and Yu, 1999, Ritz et al., 2000, Ritz et al., 2002, Wilhelm and Ritz, 2005). Specifically, the locations of existing air monitoring stations were mapped and overlaid with a map of LA FANS residential neighborhoods (census tracts) using ArcView GIS software (Version 3.3; ESRI, Redlands, CA). Using U.S. Census Block (2000) population densities, we also located the population-weighted centroid of each census tract. The final overlay was an elevation map for the air basin. The LA FANS residential census tracts (based on year 2000 boundaries) were then linked (manually) to existing monitoring stations taking into account not only distance, but geographical factors and the population distribution within tracts. For example, in cases where major geographical features (mountains) lay in between the nearest monitoring station and a tract, a linkage was not made. The next nearest station was used, or in some cases, the tract was left unlinked (see below). For larger census tracts, the population-weighted centroid helped confirm whether the majority of the population was in relatively close proximity to the nearest station even though other (less populated) portions of the tract were much farther away. This only impacted two census tracts, since most of the study region was urbanized with small tracts (average area of 3.9 km^2). There were 14 CO stations, 15 NO_2 and O_3 stations, 10 $PM_{2.5}$ stations and 8 PM_{10} stations with measurement data available for the study period. On average, population-weighted census tract centroids were 6.8 km from CO, NO_2, and O_3 monitoring stations (range of 0.23–15.4 km), 8.2 km from $PM_{2.5}$ stations (range of 0.23–25.7 km), and 9.7 km from PM_{10} stations (range of 0.23–24.3 km).

For each subject, we estimated annual average concentrations of carbon monoxide (CO), NO_2, O_3, PM_{10} and $PM_{2.5}$ for the one-year period prior to the interview date (to correspond to the time period for assessment of asthma symptoms) based on hourly measurements for the gaseous pollutants (CO, NO_2, and O_3); 24-hour average measurements taken daily or every 6 and 3 days were used for PM_{10} and $PM_{2.5}$, respectively. Two (out of 90) census tracts were not linked to a monitoring station because the census tracts were located too far from and/or in a different geographic region (mountain or desert) than the nearest monitoring station (resulting in exclusion of 67 children). One additional census tract was not assigned to a $PM_{2.5}$ station for the same reasons (resulting in 93 children with missing $PM_{2.5}$ data).

Individual, Family and Neighborhood Level Risk Factors

A number of individual, family and neighborhood-level characteristics were considered for inclusion in our models. Individual-level risk factors considered were child's race/ethnicity, age, gender, health insurance status, and whether the child had a usual source of sick care and one or more well visits during the previous 12 months (Table 1).

At the family level, we examined the following measures of socioeconomic status (SES): family income (as percent of the federal poverty limit [FPL]), homeowner status (yes/no), non-housing assets, use of public assistance in previous 12 months, primary caregiver (PCG) education (years), and parents' employment status. We also evaluated a number of family-level neighborhood perception variables, where the randomly-selected adult participant from each family was asked to rate their overall neighborhood satisfaction and opinion of neighborhood safety, cohesion and support (see Table 1 for a listing of these variables). The overall neighborhood cohesion score was based on the average of responses to a series of questions asking whether the neighborhood was close-knit, whether neighbors get along, are willing to help each other, share the same values, can be trusted, and whether adults look out for and discipline children in the neighborhood as needed (see Table 1 for more details). Participants were also asked about the number of other adults they recognize in their neighborhood. The neighborhood support score was based on the average of responses (1=often, 2=sometimes, 3=rarely, 4=never) to the following questions: (a) How often do neighbors do favors for each other; (b) How often do neighbors watch each others' property; and (c) How often do neighbors ask for advice. Adults were also asked about the number of friends and relatives living in the neighborhood, group participation in the previous 12 months, and number of conversations with and level of closeness to neighbors. Based on the design of the LA FANS survey, these perception questions were answered by the PCG for 52% of the families, by the PCG's spouse or partner for 28% of the families and by another adult in the household for 14% of the families (6% had missing data on this variable). The neighborhood definition was not specified for these responses, i.e., responses pertained to each individual's own definition of their neighborhood. Finally, we examined the importance of PCG nativity (US- or foreign-born), family type (single or dual parent family), PCG current martial status, and PCG current smoking status.

At the neighborhood level, we constructed a census tract-level disadvantage score based on US Census 2000 data similar to Cohen et al. (2006). This continuous index of neighborhood socioeconomic conditions represents the average of four measures for each tract: percent poor families, percent households on public assistance, percent female-headed families, and percent male unemployment. Similar to Cohen et al. (2006), a census cross-walk was used to relate 2000 data to 1990 tract boundaries (the original sampling frame for LA FANS). Other census-based measures included the percent of the tract population that lived in the same house 5 years ago (as a measure of neighborhood stability) and whether there was a dominant racial/ethnic group in the tract (as a measure of neighborhood homogeneity) (Prentice, 2006). Finally, we averaged the neighborhood cohesion scores and opinions of neighborhood safety across all LA FANS adults living in the same census tract as additional measures of neighborhood quality.

Statistical analysis

To examine associations between air pollution and individual, family and neighborhood characteristics, we calculated correlation coefficients and performed a factor analysis (using principal components analysis for initial factor extraction and varimax rotation). We used logistic regression to evaluate associations between outdoor air pollution and asthma, comparing asthmatics with and without exacerbations to nonasthmatics, and also asthmatics with exacerbations to asthmatics without exacerbations. A two-level model with a random intercept for family was used to account for non-independence of siblings (i.e., clustering at the family-level). We evaluated univariate associations and changes in point estimates and 95% confidence intervals (CIs) for air pollution association measures (odds ratios) when entering each individual, family and neighborhood level risk factor into the models. We adjusted for the following variables in all models based on subject-matter criteria, correlations between variables, and impact on estimates (i.e., whether their inclusion changed associations estimates by at least 10% (Rothman and Greenland, 1998): child's age, gender, race/ethnicity, and insurance status, homeowner status (yes/no), PCG education, PCG marital status, PCG nativity, and number of relatives in neighborhood. This research was approved by the UCLA Office for Protection of Research Subjects.

Results

Of the 3,114 LA FANS Wave One children included in our analyses, 345 had ever received a doctor's diagnosis of asthma (11%) and 144 of these reported suffering asthma attacks in the past 12 months (42%), according to PCG interview responses. Table 1 shows univariate associations between individual, family and neighborhood-level characteristics and asthma. At the individual level, likelihood of reporting an asthma diagnosis and attacks in the previous 12 months was higher for boys and African American children, and increased with age. The odds of reporting asthma with attacks was lower for Hispanic children, but not the odds of having received an asthma diagnosis. Those who were uninsured or only partially insured during the previous year and children of foreign-born PCGs had lower odds of asthma, especially asthma with attacks. Based on family-level characteristics, children with lower SES (measured by family income, homeowner status, non-housing assets, and PCG education level) were less likely to have asthma with attacks reported than higher SES children. This pattern was not evident or not as strong for asthma without attacks. Children in families reporting low neighborhood support had higher odds of both asthma outcomes, while those from families reporting no relatives living in the neighborhood were only more likely to report asthma with attacks. Children from single parent families and unmarried families had higher odds of both asthma outcomes, as did children of PCGs who reported smoking. Based on neighborhood-level characteristics, children living in less cohesive and safe neighborhoods (based on the average opinion of all LA FANS adults in a given census tract) and with more economic disadvantage (based on US Census data also averaged at the census tract level) had lower odds of asthma with attacks being reported. A similar pattern emerged for asthma without attacks, but relations were not as strong. Odds of both asthma outcomes appeared elevated for children living in census tracts where there was not one predominant race/ethnicity.

Associations between Family and Neighborhood-Level Characteristics and Air Pollution

Correlation coefficients and a factor analysis were used to evaluate relations among annual average air pollution exposure estimates and selected family and neighborhood level sociodemographic variables (see Table 2 for factor analysis results; correlation coefficients are discussed below). Extraction using principal components followed by varimax rotation suggest the 22 selected variables can be summarized by three factors. The first "neighborhood quality" factor reflects both subjective (opinions of cohesion and safety at the neighborhood and family level) and objective (neighborhood level economic disadvantage, family level income and non-housing assets) measures of neighborhood quality. Pearson correlations suggested that CO and NO_2 levels tended to increase as neighborhood quality decreased, while the opposite trend was observed for O_3, but overall the air pollution metrics were not strongly correlated with the neighborhood quality measures (r~0.3 or lower). The second "air pollution" factor reflects the relatively strong correlations between average pollutant concentrations, especially for CO, NO_2 and O_3. While CO and NO_2 were positively correlated (Pearson correlation coefficient (r) of 0.67), both were negatively correlated with O_3 (r~−0.7). Correlations between $PM_{2.5}$ and PM_{10} and these pollutants, however, were more moderate (PM2.5: r~0.4 for CO and NO_2 and −0.4 for O_3; PM_{10}: r=0.49 for NO_2, 0.25 for CO and −0.23 for O_3). The third "neighborhood support, social ties" factor reflected the correlations among family level ratings of neighborhood support and social ties/networks. Air pollutant levels were not correlated with family ratings of neighborhood support and social ties reflected in both low loadings of the air pollution variables on this factor and low Pearson correlation coefficients (r of 0.16 or lower). Two variables, family level opinion of neighborhood cohesion and number of relatives living in the neighborhood loaded similarly on the first and third factors suggesting these variables represented aspects of both groupings.

Spatially, neighborhoods in the downtown, urban core areas of the County had the highest CO and NO_2 levels, while O_3 was elevated in the more eastern and south-eastern parts of the County. Levels of PM_{10} were most elevated in the eastern part of the County, especially in the south east, but also somewhat elevated in the downtown urban area. Levels of $PM_{2.5}$ were elevated in the urban core, but also in the south east. Although "neighborhood quality" as defined by variables such as the census tract level disadvantage score tended to be lowest in the downtown urban core, there were also other areas characterized by higher deprivation, including some areas of the San Fernando Valley and near the Harbors. The overall low correlations between the "neighborhood quality", "air pollution", and "neighborhood support" factors described above suggest that SES, social support, and air pollution follow complex patterns in LA County. These factors identified in our analyses only explained about 45% of the variance of the original variables. Thus, rather than relying on such weak proxies in our logistic regression models for asthma, we considered the relations identified between variables loading on the same factor when constructing our final most parsimonious adjusted model.

Associations between Air Pollution and Reported Asthma

When comparing children with doctor-diagnosed asthma and reports of one or more attacks in the previous year to nonasthmatics, we estimated an approximately 64% increase in odds of this outcome per 1 pphm increase in annual average O_3 in an unadjusted model (OR=1.64, 95% CI=1.15–2.33). However, adjustment for home ownership, insurance status of the child, PCG nativity, education, and marital status, and the family's report of relatives living in their neighborhood reduced the estimate to essentially a null finding (Table 3). Adding PM_{10} and $PM_{2.5}$ to the model did not change this result (CO, NO_2 and O_3 concentrations were considered too highly correlated to be included in the same models).

We also estimated a 46% increase in odds of reporting a doctor-diagnosis of asthma without attacks in the previous year per 1 pphm increase in O_3 based on a crude model (OR=1.46, 95% CI=1.07–1.99). However, this effect estimate did not change appreciably when any of the variables noted above were added (Table 3). Adjusting for all variables simultaneously and adding PM_{10} and $PM_{2.5}$ to the model resulted in an OR essentially the same as the crude result but less precise (OR=1.45, 95% CI=0.93–2.25). Most of the association between O_3 and asthma without attacks appeared isolated to those children experiencing very high exposures (greater than the 90^{th} percentile of 2.38 pphm). Very weak crude associations between PM_{10} and asthma without attacks in the previous 12 months increased when we added O_3 and $PM_{2.5}$ to the model (OR=1.46, 95% CI=0.96–2.22) (Table 3). When focusing on children most highly exposed to PM_{10} (>45.9 μg/m^3), we observed an 86% increase in the odds of asthma without attacks in the previous 12 months (OR=1.86, 95% CI=1.13–3.08).

In a sub-analysis, we compared asthmatics with attacks to asthmatics without attacks in the past year and observed associations that distinguished these two groups only for CO. We estimated a 57% increase in odds of attacks in the previous 12 months per 1 ppm increase in annual average CO among asthmatic children (OR=1.57, 95% CI=0.71–3.48) (Table 4). Adjustment for race/ethnicity and age increased this estimate to a 64% increase per 1 ppm CO. Further adjustment for home ownership, child's insurance status, PCG nativity, education level and marital status, and whether the family had relatives in the neighborhood did not change the estimate appreciably. Adjusting for these variables simultaneously, we estimated an approximately 2-fold increase in risk of attacks in the previous 12 months per 1 ppm increase in CO (OR=2.33, 95% CI=1.03–5.25). Similar to what we observed for O_3 and PM_{10}, most of the association between CO and asthma attacks appeared isolated to children with very high exposures (greater than the 90^{th} percentile of 1.77 ppm).

Discussion

Using the LA FANS dataset in combination with US Census and government air monitoring data, we were able to examine associations between outdoor air pollution and a large number of family- and neighborhood-level characteristics in Los Angeles neighborhoods. In general, we found that CO and NO_2 levels increased and O_3 levels decreased with decreasing neighborhood quality, assessed based on objective measures such as economic disadvantage and subjective measures such as average ratings of neighborhood safety and cohesion by LA FANS participants. However, correlations between these factors and pollution levels were fairly low (r~0.3 or less). Air pollution levels were not correlated with family-level ratings of neighborhood support and level of social ties and networks.

Based on our models, LA FANS children living in high O_3 areas had higher odds of doctor-diagnosed asthma but not higher odds of reporting attacks in the previous 12 months. Similar to O_3, associations between PM_{10} levels and asthma were limited to asthmatics without attacks in the previous 12 months, and the very highly exposed (i.e., exposures above the 90^{th} percentile of 45.9 $\mu g/m^3$). When limiting comparisons to diagnosed asthmatics only, children living in high CO areas had higher odds of reporting attacks in the previous 12 months. Since CO is emitted directly by motor vehicles and does not readily react in the atmosphere to form other compounds, it is often considered a marker for the suite of pollutants released in exhaust. Measurement data indicate levels of CO are spatially correlated with other exhaust constituents, such as ultrafine particles in the LA Basin (Zhu et al., 2002a, Zhu et al., 2002b). There is a growing literature linking various traffic metrics to asthma symptoms and exacerbations (Salam et al., 2008, Brauer et al., 2007, Bayer-Oglesby et al., 2006, Gauderman et al., 2007). Thus, the observed associations with CO could reflect toxic action of unmeasured traffic exhaust compounds.

We also performed analyses stratifying on the census tract level indicators of neighborhood quality and two family-level measures of social support (number of relatives in the neighborhood and the overall neighborhood social support rating). When stratifying on median values of the census tract level variables, in general, O_3 effect estimates for asthmatics without attacks in the previous 12 months appeared greater in neighborhoods considered to be more cohesive and safe and with lower economic disadvantage, although 95% CIs for most stratum-specific estimates overlapped widely due to our limited sample size. The strongest difference was observed for the census tract level rating of neighborhood cohesion; we estimated a 2-fold increase in odds of asthma without attacks per 1 pphm increase in O_3 (OR=2.07, 95% CI=1.09–3.93) for children living in neighborhoods considered to be more cohesive and essentially no association with O_3 for children living in less cohesive neighborhoods (OR=1.03, 95% CI=0.52–2.02). This could be indicative of better reporting by parents and/or less exposure misclassification (due to less residential mobility) among subjects in high SES areas. We did not observe differences in effect estimates when stratifying on median values of the social support variables.

One limitation of the present analyses is the cross-sectional nature of the data; specifically, potential bias caused by temporal ambiguity between exposure and disease. We did not have lifetime residential histories for these children (we assigned monitoring stations based on current home location) and did not know the date of asthma diagnosis. The magnitude of resulting bias depends on the residential mobility patterns of the LA FANS children. Information on residential history was collected for the two years prior to the interview date. Based on these data, approximately 67% of the children lived regularly with the interviewed family and did not move during this period. Of the approximately 27% of children who lived regularly with a family that did move, only 35% moved to a different census tract (~9% of total families) and only 13% moved to a census tract with a different air monitor assignment (~4%

of total families) based on residential data for the year prior to the interview. Based on these data, the majority (94%) of children lived in the same home for at least a year prior to interview or if they did move, tended to stay in the same census tract or in the same "monitoring area". When we stratified on the median value of our census measure of residential stability (i.e., percent of tract population living in the same home as 5 years ago), point estimates for CO and to a lesser extent PM_{10} were greater for those living in neighborhoods with greater stability. This suggests that exposure misclassification (if assumed non-differential) may be impacting our estimates. Ozone effect estimates were largely similar when stratifying on residential stability, which may reflect the spatially more homogeneous distribution of this pollutant.

A second issue is the outcome assessment which relied on parental reports of health care provider-diagnosed asthma and attacks in the previous 12 months. The higher odds of these outcomes for wealthier, educated individuals with healthcare could reflect under-reporting among the more disadvantaged. The strong negative relation between PCG nativity and reporting asthma with attacks (and to a lesser extent also for asthma without attacks) suggests that under-reporting may be an issue especially for children of foreign-born parents. Based on data from a LA county-wide random sample of 6,004 children collected during September 1999-April 2000 using the same questions regarding asthma, Simon et al. (2003) reported the highest prevalence of asthma among black children (15.8%), followed by whites (7.3%) and Asians (6%), and the lowest among children of Latino ethnicity (3.9%); differences persisted after adjustment for income, measures of health care access, and other covariates. Asthma prevalence was inversely related to income in all racial/ethnic groups except for Spanish-speaking Latinos. The authors concluded the lower prevalence and lack of an association with income among Latino children from Spanish-speaking households could be due to either health-protective influences in the family and community in the less acculturated or a higher level of undiagnosed asthma or less ability to communicate a health care provider's asthma diagnosis in an interview format. For LA FANS children, Sastry and Pebley (2003) previously reported that Latino children were more likely to be rated by care givers as being in fair health compared to whites and Asians, despite the lower percentages of Latino children reported to have had asthma, asthma attacks in the past 12 months and chronic ear infections than all other children. Further analysis based on mother's place of birth showed that Latino children from US-born or non-Mexican-born mothers were more likely to be rated as being in excellent health compared to children of Mexican-born mothers, while the latter had the highest percentage of children in fair health. However, Latino children from US-born or non-Mexican born mothers had an asthma and chronic ear infection prevalence similar to or slightly higher than whites, while children of Mexican-born mothers again had a lower prevalence. Assuming that ear infections and asthma make an important contribution to overall child health, this contradictory observation suggests some reporting bias may be present among recent Mexican immigrants.

Relying on ambient air monitoring stations to assess air pollution exposure likely resulted in exposure misclassification, especially for pollutants that are known to have concentrations that vary over short distances such as CO and related exhaust toxins (e.g., ultrafine particles) (Sioutas et al., 2005, Zhou and Levy, 2007). We have discussed this issue extensively in previous reports (Ritz and Yu, 1999, Ritz et al., 2000, Wilhelm and Ritz, 2003, Wilhelm and Ritz, 2005). We were also missing data on some potentially important confounders such as sources of indoor allergens (e.g., pets and molds). In a previous study of Southern Californian children, adjustment for presence of one or more pets in the home, mildew or cockroaches did not substantially alter reported cross-sectional relations between community-level measures of air pollution (PM_{10} and NO_2) and bronchitic symptoms in asthmatic children after adjustment for age, sex, race/ethnicity, school grade, and membership in a health insurance plan (McConnell et al., 1999). In regards to assessing environmental tobacco smoke exposure, our data was limited to knowing whether the PCG was a current smoker and we did not know which other household members also smoked. However, children may be most exposed to second-hand smoke from PCGs and our data showed strong associations with PCG smoking status among children who had suffered asthma attacks in the past 12 months and to a lesser extent for asthmatic without attacks.

A second LA FANS survey (Wave Two) that includes families who participated in Wave One plus a sample of new entrants into these neighborhoods is currently being conducted. The asthma outcome assessment has been expanded to include date of diagnosis, symptoms in addition to diagnoses, family history of asthma, and measures of lung function using portable spirometers in children 5 years and older. In addition, questions on residential history and the home environment have been added. In conjunction with this interview, we are collecting measurements of nitrogen oxides (NO_x) at approximately 200 locations throughout the LA FANS neighborhoods as a marker of vehicle exhaust and these data will be used to generate air pollution exposure surfaces for the children in Wave Two through land use-based regression (LUR) modeling (e.g., Sahsuvaroglu et al., 2006). Thus, we will be able to address the limitations noted above in future analyses.

Despite the limitations noted, the LA FANS data provide a unique way to look at environmental exposures in conjunction with other potentially important co-factors for asthma. Since asthma is a multifactorial disease, information on family and neighborhood-level characteristics that may be indicative of psychosocial stress and other risk factors are needed if these either confound the air pollution relations or increase susceptibility to air pollutants in children. After adjusting for a variety of SES and psychosocial factors at the family and neighborhood level, we still observed increased odds of asthma for children residing in areas of high air pollution in LA. The LA FANS Wave Two data will increase our ability to examine the interplay of these factors on asthma in disadvantaged children, i.e. to assess effect measure modification due to psychosocial factors.

Conclusions

In LA FANS both outdoor air pollution and a number of family and neighborhood-level characteristics were associated with asthma in children. In general, we found that CO and NO_2 levels increased and O_3 levels decreased as neighborhood quality decreased. However, correlations between these factors and pollution levels were fairly low (r~0.3 or less). Air pollution levels were not correlated with family ratings of neighborhood support and level of social ties and networks. Based on our models, LA FANS children living in areas with high O_3 and PM_{10} levels had greater odds of reporting doctor-diagnosed asthma without attacks in the previous 12 months. However, similar relations were not observed for doctor-diagnosed asthma with attacks in the previous 12 months. This may be due to under-reporting of diagnoses and symptoms among certain subpopulations. We also found that LA FANS children diagnosed with asthma and living in areas with high CO levels had greater odds of reporting attacks in previous 12 months. Since CO is directly emitted from motor vehicles and does not readily react in the atmosphere to form other compounds, this association may be indicative of the influence of a co-occurring pollutant or mixture of pollutants in traffic exhaust. We will be able to examine these questions further once Wave Two data collection is complete.

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Table 1

Number (Percent) of Subjects in Each Outcome Group by Individual-, Family-, and Neighborhood-Level Demographic Characteristics and Crude Odds Ratios (95% CI) for Asthma

Parameter	1 Asthmatics w/exacerbations (n=144)	2 Asthmatics w/no exacerbations (n=201)	3 Nonasthmatics (n=2769)	1 vs. 3 Crude OR (95% CI)	2 vs. 3 Crude OR (95% CI)
Individual Level					
Gender					
Female	52 (36.1)	79 (39.3)	1385 (50.0)	1.00	1.00
Male	92 (63.9)	122 (60.7)	1384 (50.0)	1.81 (1.26–2.59)	1.57 (1.16–2.13)
Age (years)					
≤5	32 (22.2)	47 (23.4)	1021 (36.9)	0.59 (0.36–0.98)	0.67 (0.43–1.03)
6-<10	35 (24.3)	46 (22.9)	674 (24.3)	1.00	1.00
10-<15	53 (36.8)	65 (32.3)	702 (25.4)	1.46 (0.93–2.31)	1.37 (0.91–2.06)
≥15	24 (16.7)	43 (21.4)	372 (13.4)	1.25 (0.72–2.18)	1.73 (1.09–2.74)
Race/ethnicity					
Non-Hispanic White	29 (20.1)	34 (16.9)	503 (18.2)	1.00	1.00
Hispanic	62 (43.1)	120 (59.7)	1809 (65.3)	0.58 (0.36–0.94)	0.98 (0.64–1.48)
African American	37 (25.7)	26 (12.9)	221 (8.0)	3.07 (1.78–5.32)	1.81 (1.02–3.20)
Asian/Other	16 (11.1)	21 (10.5)	236 (8.5)	1.18 (0.61–2.29)	1.32 (0.72–2.41)
Health insurance during past 12 months					
Insured	146 (80.7)	188 (88.7)	1927 (77.1)	1.00	1.00
Partially insured or not insured	35 (19.3)	15 (11.3)	572 (22.9)	0.42 (0.24–0.73)	0.80 (0.54–1.20)
Usual source of sick care					
No	14 (9.9)	24 (11.9)	302 (11.0)	0.89 (0.49–1.59)	1.11 (0.70–1.77)
Yes	128 (90.1)	177 (88.1)	2457 (89.1)	1.00	1.00
Well visit in past 12 months					
No	65 (32.8)	42 (29.4)	674 (24.7)	1.28 (0.87–1.88)	1.52 (1.10–2.11)

Parameter	1 Asthmatics w/exacerbations (n=144)	2 Asthmatics w/no exacerbations (n=201)	3 Nonasthmatics (n=2769)	1 vs. 3 Crude OR (95% CI)	2 vs. 3 Crude OR (95% CI)
Yes	133 (67.2)	101 (70.6)	2054 (75.3)	1.00	1.00
Family Level					
Family income (as Percent FPL)					
<100%	25 (17.6)	60 (29.9)	921 (33.7)	0.33 (0.20–0.54)	0.76 (0.51–1.12)
100–199%	32 (22.5)	62 (30.9)	753 (27.6)	0.51 (0.32–0.82)	0.97 (0.65–1.43)
200–299%	28 (19.7)	19 (9.5)	349 (12.8)	1.00 (0.61–1.65)	0.63 (0.36–1.10)
≥300%	57 (40.1)	60 (29.9)	707 (25.9)	1.00	1.00
Homeowners					
Yes	72 (50.7)	82 (40.8)	1021 (37.4)	1.00	1.00
No	70 (49.3)	119 (59.2)	1709 (62.6)	0.57 (0.40–0.82)	0.86 (0.63–1.17)
Non-housing assets (dollars)					
<500	28 (19.7)	43 (21.4)	648 (23.7)	0.58 (0.35–0.96)	0.88 (0.56–1.39)
500-<44000	69 (48.6)	112 (55.7)	1468 (53.8)	0.63 (0.42–0.95)	1.02 (0.70–1.49)
≥44000	45 (31.7)	46 (22.9)	614 (22.5)	1.00	1.00
Public assistance in past 12 months					
No	102 (71.8)	146 (72.6)	2181 (79.9)	1.00	1.00
Yes	40 (28.2)	55 (27.4)	549 (20.1)	1.59 (1.06–2.36)	1.52 (1.08–2.16)
PCG’s education (years)					
<12	29 (20.3)	63 (31.8)	1172 (42.7)	0.31 (0.20–0.48)	0.62 (0.43–0.88)
12	30 (21.0)	43 (21.7)	492 (17.9)	0.77 (0.49–1.22)	1.03 (0.69–1.55)
>12	84 (58.7)	92 (46.5)	1080 (39.4)	1.00	1.00
Parent’s employment status					
One or both employed	120 (83.3)	168 (84.0)	2402 (86.9)	1.00	1.00

Parameter	1 Asthmatics w/exacerbations (n=144)	2 Asthmatics w/no exacerbations (n=201)	3 Nonasthmatics (n=2769)	1 vs. 3 Crude OR (95% CI)	2 vs. 3 Crude OR (95% CI)
Both unemployed	24 (16.7)	32 (16.0)	361 (13.1)	1.35 (0.84–2.17)	1.29 (0.84–1.96)
Foreign born status of PCG					
US born	97 (69.3)	86 (43.4)	953 (35.1)	1.00	1.00
Foreign born	43 (30.7)	112 (56.6)	1762 (64.9)	0.23 (0.16–0.34)	0.69 (0.51–0.94)
Neighborhood satisfaction					
Very satisfied	36 (26.3)	41 (21.5)	502 (19.4)	1.00	1.00
Satisfied or Neutral (if volunteered)	75 (54.7)	115 (60.2)	1610 (62.3)	0.64 (0.42–0.99)	0.87 (0.59–1.29)
Dissatisfied or Very dissatisfied	26 (19.0)	35 (18.3)	471 (18.2)	0.77 (0.44–1.33)	0.91 (0.55–1.49)
How safe to walk alone after dark in this neighborhood					
Completely safe	32 (23.7)	44 (23.2)	467 (18.2)	1.00	1.00
Fairly safe or Somewhat dangerous	91 (67.4)	139 (73.2)	1976 (76.9)	0.66 (0.43–1.03)	0.74 (0.50–1.08)
Extremely dangerous	12 (8.9)	7 (3.7)	126 (4.9)	1.41 (0.67–2.95)	0.59 (0.25–1.39)
No. adults you recognize in neighborhood					
Many adults or most or all adults	71 (51.8)	78 (40.8)	1203 (46.6)	1.00	1.00
A few adults or no adults	66 (48.2)	113 (59.2)	1378 (53.4)	0.80 (0.56–1.15)	1.28 (0.93–1.76)
Neighborhood cohesion score[1]					
<2.52 (median) (higher)	75 (55.6)	91 (48.4)	1418 (55.6)	1.00	1.00
≥2.52	60 (44.4)	97 (51.6)	1131 (44.4)	1.00 (0.70–1.44)	1.35 (0.99–1.85)
No. relatives living in neighborhood					
Any	39 (28.5)	88 (46.1)	1066 (41.4)	1.00	1.00
None	98 (71.5)	103 (53.9)	1511 (58.6)	1.80 (1.21–2.66)	0.82 (0.60–1.12)
No. friends living in neighborhood					
Any	88 (64.2)	133 (69.6)	1820 (70.6)	1.00	1.00

Parameter	1 Asthmatics w/exacerbations (n=144)	2 Asthmatics w/no exacerbations (n=201)	3 Nonasthmatics (n=2769)	1 vs. 3 Crude OR (95% CI)	2 vs. 3 Crude OR (95% CI)
None	49 (35.8)	58 (30.4)	757 (29.4)	1.35 (0.92–1.97)	1.05 (0.75–1.48)
No. groups participated in past 12 months					
Any	54 (39.4)	66 (34.6)	720 (27.9)	1.00	1.00
None	83 (60.6)	125 (65.5)	1857 (72.1)	0.58 (0.40–0.84)	0.72 (0.52–1.01)
Neighborhood support score[2]					
1-<2 (higher)	41 (29.9)	45 (23.6)	799 (31.0)	1.00	1.00
2-<4	78 (56.9)	129 (67.5)	1633 (63.4)	0.93 (0.62–1.40)	1.41 (0.98–2.04)
≥4	18 (13.1)	17 (8.9)	142 (5.5)	2.55 (1.36–4.77)	2.22 (1.18–4.16)
No. neighbors talked to for 10 minutes in past 30 days					
Any	109 (79.6)	160 (83.8)	2159 (83.8)	1.00	1.00
None	28 (20.4)	31 (16.2)	417 (16.2)	1.33 (0.85–2.09)	1.00 (0.65–1.53)
How close are you to closest neighbor					
Close friends, friendly but not close, acquaintances	130 (95.6)	179 (93.7)	2429 (94.3)	1.00	1.00
Don’t get along with, don’t know or don’t have any contact with neighbors	6 (4.4)	12 (6.3)	147 (5.7)	0.75 (0.31–1.79)	1.13 (0.59–2.15)
Family type					
Both parents present	96 (66.7)	137 (68.2)	2161 (78.0)	1.00	1.00
Single parent or don’t live with either parent	48 (33.3)	64 (31.8)	608 (22.0)	1.81 (1.24–2.64)	1.70 (1.22–2.37)
PCG current marital status					
Married or living with partner	93 (64.6)	142 (70.7)	2151 (77.7)	1.00	1.00
Unmarried	51 (35.4)	59 (29.4)	618 (22.3)	1.96 (1.35–2.84)	1.47 (1.05–2.06)
PCG current smoking status					
Yes	28 (20.1)	25 (12.6)	256 (9.5)	2.49 (1.57–3.97)	1.40 (0.87–2.24)

Parameter	1 Asthmatics w/exacerbations (n=144)	2 Asthmatics w/no exacerbations (n=201)	3 Nonasthmatics (n=2769)	1 vs. 3 Crude OR (95% CI)	2 vs. 3 Crude OR (95% CI)
No	111 (79.9)	173 (87.4)	2443 (90.5)	1.00	1.00
Neighborhood Level					
Census tract level rating of neighborhood cohesion[3]					
<2.32 (higher)	49 (34.0)	60 (29.9)	633 (22.9)	1.00	1.00
2.32-<2.59	40 (27.8)	51 (25.4)	682 (24.6)	0.75 (0.47–1.18)	0.78 (0.51–1.18)
2.59-<2.76	26 (18.6)	44 (21.9)	718 (25.9)	0.45 (0.27–0.75)	0.63 (0.41–0.97)
≥2.76	29 (20.1)	46 (22.9)	736 (26.6)	0.50 (0.30–0.81)	0.65 (0.42–0.99)
Census tract level rating of neighborhood safety[4]					
<1.86 (higher)	44 (30.6)	59 (29.4)	646 (23.3)	1.00	1.00
1.86-<2.22	47 (32.6)	50 (24.9)	667 (24.1)	1.04 (0.66–1.62)	0.82 (0.54–1.24)
2.22-<2.57	23 (16.0)	45 (22.4)	748 (27.0)	0.44 (0.26–0.75)	0.64 (0.42–0.99)
≥2.57	30 (20.8)	47 (23.4)	708 (25.6)	0.61 (0.37–1.01)	0.72 (0.47–1.10)
Tract–level disadvantage[5]					
<0.10 (lower)	43 (29.9)	57 (28.4)	618 (22.3)	1.00	1.00
0.10-<0.15	43 (29.9)	47 (23.4)	709 (25.6)	0.87 (0.55–1.38)	0.71 (0.46–1.09)
0.15-<0.20	27 (18.8)	39 (19.4)	676 (24.4)	0.56 (0.34–0.94)	0.61 (0.39–0.95)
≥0.20	31 (21.5)	58 (28.9)	766 (27.7)	0.57 (0.35–0.94)	0.82 (0.54–1.22)
Percent of tract in same home 5 years ago[6]					
<0.46	25 (17.4)	56 (27.9)	722 (26.1)	0.66 (0.39–1.13)	1.03 (0.69–1.56)
0.46-<0.52	30 (20.8)	46 (22.9)	672 (24.3)	0.86 (0.51–1.43)	0.91 (0.59–1.39)
0.52-<0.58	51 (35.4)	44 (21.9)	642 (23.2)	1.56 (0.99–2.47)	0.91 (0.59–1.41)
≥0.58	38 (26.4)	55 (27.4)	733 (26.5)	1.00	1.00

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Parameter	1 Asthmatics w/exacerbations (n=144)	2 Asthmatics w/no exacerbations (n=201)	3 Nonasthmatics (n=2769)	1 vs. 3 Crude OR (95% CI)	2 vs. 3 Crude OR (95% CI)
One predominant race/ethnicity in census tract[6]					
Yes	91 (63.2)	139 (69.2)	2061 (74.4)	1.00	1.00
No	53 (36.8)	62 (30.9)	708 (25.6)	1.73 (1.20–2.51)	1.32 (0.94–1.84)

(1) Average of responses for the following questions (with reverse coding where necessary): (a) This is a close–knit neighborhood; (b) There are adults kids can look up to; (c) People are willing to help their neighbors; (d) Neighbors generally don't get along; (e) Adults watch out that kids are safe; (f) People in neighborhood don't share same values; (g) People in neighborhood can be trusted; (h) Parents in neighborhood know kids friends; (i) Adults in neighborhood know local kids' (j) Parents in neighborhood know each other; (k) Neighbors do something if kid hangs out; (l) Would do something if kid does graffiti; (m) Would scold kid if showing disrespect. Responses for a–j were: 1=strongly agree, 2=agree, 3=unsure, 4=disagree, 5=strongly disagree; Responses for k–m were: 1=very likely, 2=likely, 3=unsure, 4=unlikely, 5=very unlikely.

(2) Average of responses (1=often, 2=sometimes, 3=rarely, 4=never) for the following questions: (a) How often do neighbors do favors for each other; (b) How often do neighbors watch each others property; (c) How often do neighbors ask advice.

(3) This is the average of the neighborhood cohesion score for all adult respondents in a given census tract.

(4) This is the average of the neighborhood safety responses for all adult respondents in a given census tract using the following numeric responses for each response: 1=completely safe, 2=fairly safe, 3=somewhat dangerous, 4=extremely dangerous.

(5) This is the average of the following four variables for each census tract (based on U.S. Census 2000 data): percent poor families, percent households on public assistance, percent female headed families, percent male unemployment.

(6) Based on U.S. Census 2000 data.

Table 2

Varimax rotation, principal component factors for annual average pollution concentrations and family- and census tract- level sociodemographic variables

Variable	Factor Loadings			Communality (h_i^2)	Specificity (u_i^2)
	F_1	F2	F3		
Neighborhood quality					
Census tract level opinion of neighborhood cohesion[1]	**0.88**	0.05	0.09	0.79	0.21
Census tract level opinion of neighborhood safety[1]	**0.88**	0.02	0.06	0.78	0.22
Census tract level disadvantage score	**0.86**	−0.002	0.08	0.75	0.25
PCG education (years)	**−0.62**	−0.16	0.05	0.41	0.59
Family level income (% FPL)	**−0.58**	−0.14	−0.009	0.36	0.64
Family level neighborhood satisfaction[1]	**0.55**	0.009	0.27	0.38	0.62
Family level opinion of neighborhood safety[1]	**0.48**	−0.09	0.15	0.26	0.74
Non−housing assets	**−0.47**	−0.13	0.02	0.24	0.76
No. of groups participated in during past 12 month	**−0.40**	−0.07	−0.16	0.19	0.81
No. of relatives in neighborhood	**−0.27**	−0.08	0.23	0.13	0.87
Air pollution[2]					
NO_2	0.33	**0.83**	0.007	0.80	0.20
CO	0.25	**0.78**	−0.002	0.66	0.34
O_3	−0.25	**−0.77**	0.005	0.65	0.35
$PM_{2.5}$	0.002	**0.70**	−0.03	0.49	0.51
PM_{10}	−0.10	**0.59**	0.05	0.36	0.64
Census tract level % in same house as 5 yrs ago	−0.37	**0.41**	−0.08	0.31	0.69
Support, Social Ties					
Family level opinion of neighborhood support[1]	0.14	0.02	**0.72**	0.54	0.46
No. of neighbors spoke to in past 30 days[3]	0.005	0.06	**0.68**	0.46	0.54
No. of friends living in neighborhood[3]	−0.04	0.02	**0.60**	0.36	0.64
How close do you feel to closest neighbor[3]	0.06	−0.06	**0.56**	0.33	0.67
Family level opinion of neighborhood cohesion[1]	0.48	0.01	**0.54**	0.52	0.48
No adults you recognize in neighborhood[3]	0.16	−0.02	**0.47**	0.25	0.75
Variance explained	4.67	2.97	2.38	$\Sigma h_i^2 = 10.02$	$\Sigma u_i^2 = 11.98$

Variable	Factor Loadings			Communality (h_i^2)	Specificity (u_i^2)
	F_1	F2	F3		
Percentage of total variance	21.2	13.5	10.8	45.5	54.5

(1) High values for these measures indicate low ratings.

(2) The mean (range) of annual average air pollution concentrations were: CO: 1.1 (0.33–2.2) ppm; NO_2 3.5 (1.6–5.1) pphm; O_3 1.9 (1.1–3.8) pphm; $PM_{2.5}$ 20.7 (10.6–26.7) μg/m^3; PM_{10} 40.8 (26.5–55.6) μg/m^3

(3) These variables are dichomotously coded such that a high value (1) means less support (see also Table 1).

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Table 3

Association (Odds Ratio, 95% CI) between annual average O_3 and PM_{10} concentrations and asthma among LA FANS participants ages 0–17 years

Model	Asthmatics w/attacks vs. Nonasthmatics	Asthmatics w/o attacks vs. Nonasthmatics
O_3 (per 1 pphm)		
Crude	1.64 (1.15–2.33)	1.46 (1.07–1.99)
+ age, gender, race/ethnicity	1.43 (0.98–2.08)	1.47 (1.06–2.04)
+ age, gender, race/ethnicity, home ownership	1.40 (0.96–2.03)	1.46 (1.05–2.03)
+ age, gender, race/ethnicity, PCG education	1.37 (0.93–2.02)	1.44 (1.03–2.01)
+ age, gender, race/ethnicity, insurance status	1.34 (0.89–2.00)	1.46 (1.03–2.08)
+ age, gender, race/ethnicity, PCG foreign born	1.22 (0.83–1.77)	1.37 (0.98–1.91)
+ age, gender, race/ethnicity, PCG marital status	1.41 (0.97–2.05)	1.47 (1.06–2.03)
+ age, gender, race/ethnicity, relatives in neighborhood	1.27 (0.86–1.87)	1.50 (1.07–2.09)
+ all variables	0.99 (0.64–1.53)	1.45 (1.00–2.10)
+ all variables, PM_{10}	1.00 (0.64–1.56)	1.56 (1.05–2.32)
+ all variables, PM_{10}, $PM_{2.5}$	1.00 (0.61–1.64)	1.45 (0.93–2.25)
O_3 (+all variables, PM_{10}, $PM_{2.5}$)		
$<25^{th}$ percentile (1.65 pphm)	1.00	1.00
$\geq 75_{th}$ percentile (2.09 pphm)	1.39 (0.75–2.58)	1.28 (0.76–2.16)
$<90^{th}$ percentile	1.00	1.00
$\geq 90^{th}$ percentile (2.38 pphm)	1.19 (0.64–2.21)	1.69 (0.98–2.92)
PM_{10} (per 10 μg/m^3)		
Crude	0.94 (0.62–1.44)	1.10 (0.77–1.58)
+ age, gender, race/ethnicity	1.19 (0.77–1.82)	1.12 (0.77–1.63)
+ age, gender, race/ethnicity, home ownership	1.16 (0.75–1.78)	1.14 (0.79–1.66)
+ age, gender, race/ethnicity, PCG education	1.08 (0.70–1.67)	1.09 (0.75–1.59)
+ age, gender, race/ethnicity, insurance status	1.17 (0.74–1.84)	1.17 (0.79–1.74)
+ age, gender, race/ethnicity, PCG foreign born	1.13 (0.74–1.73)	1.12 (0.77–1.62)
+ age, gender, race/ethnicity, PCG marital status	1.20 (0.78–1.84)	1.17 (0.80–1.73)
+ age, gender, race/ethnicity, relatives in neighborhood	1.29 (0.83–2.01)	1.13 (0.78–1.65)
+ all variables	1.04 (0.65–1.67)	1.21 (0.81–1.82)
+ all variables, O_3	1.04 (0.65–1.68)	1.34 (0.90–2.00)
+ all variables, O_3, $PM_{2.5}$	1.03 (0.63–1.70)	1.46 (0.96–2.22)
PM_{10} (+all variables, O_3, $PM_{2.5}$)		
$<25^{th}$ percentile (37.6 μg/m^3)	1.00	1.00
$\geq 75^{th}$ percentile (42.9 μg/m^3)	1.15 (0.60–2.20)	1.24 (0.71–2.17)
$<90^{th}$ percentile	1.00	1.00
$\geq 90^{th}$ percentile (45.9 μg/m^3)	1.10 (0.56–2.14)	1.86 (1.13–3.08)

Table 4

Association (Odds Ratio, 95% CI) between annual average CO concentrations and asthma attacks among LA FANS participants ages 0–17 years

Model	Asthmatics w/attacks vs. Asthmatics w/o attacks
CO (per 1 ppm)	
Crude	1.57 (0.71–3.48)
+ age, gender, race/ethnicity	1.64 (0.76–3.56)
+ age, gender, race/ethnicity, home ownership	1.61 (0.74–3.47)
+ age, gender, race/ethnicity, PCG education	1.74 (0.80–3.79)
+ age, gender, race/ethnicity, insurance status	1.74 (0.77–3.92)
+ age, gender, race/ethnicity, PCG foreign born	1.61 (0.76–3.41)
+ age, gender, race/ethnicity, PCG marital status	1.72 (0.76–3.75)
+ age, gender, race/ethnicity, relatives in neighborhood	1.66 (0.81–3.41)
+ all variables	2.33 (1.03–5.25)
CO (+all variables)	
<25th percentile (0.82 ppm)	1.00
≥75th percentile (1.28 ppm)	1.54 (0.66–3.61)
<90th percentile	1.00
≥90th percentile (1.77 ppm)	6.37 (1.86–21.9)