Final Technical Report

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RFA: Airborne Particulate Matter (PM) Centers (1999)
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Topic B: Studies of Emission Sources and Related Adverse Health Effects

Objective(s) of the Research Project: When we examined associations between adverse birth outcomes and maternal air pollution exposure during pregnancy based on a cohort of Southern Californian births during 1989–1993, we found that increases in carbon monoxide (CO), particulate matter less than 10 microns (<10 μm) in aerodynamic diameter (PM_{10}), and ozone (O_3) concentrations during vulnerable pregnancy periods increased the risk of term low birth weight (LBW) (Ritz and Yu, 1999), preterm delivery (Ritz, et al., 2000), and common cardiac malformations, such as ventricular septal defects (Ritz, et al., 2002). Carbon monoxide is released directly in motor vehicle exhaust and does not react readily in the atmosphere to form other compounds. The consistently observed associations between ambient CO and adverse birth outcomes in our studies suggest that compounds in motor vehicle exhaust may affect fetal development. CO, however, may be only an easily measured and stable indicator for other compounds emitted in exhaust. For example, fine particles (F) and ultrafine particles (UF) are also released directly in vehicle exhaust, and UF number count and CO concentrations correlated almost perfectly when measured with increasing distance from a roadway out to 300 feet (Zhu, et al., 2002a,b). When we used a census-based measure of commuting level, we also found higher risk of term LBW for women who commuted more than 60 minutes to work (Ritz and Yu, 1999). These findings, along with data indicating pollutant concentrations inside vehicles are generally higher than ambient concentrations (e.g., Rodes, et al., 1998 and Fruin, 2003), suggest in-vehicle exposure to motor vehicle exhaust pollutants while commuting may also be an important risk factor for adverse birth outcomes in pregnant women.

Therefore, the first research goal of this project was to determine whether residential proximity to heavy traffic roadways, such as freeways and major arterials, affected the risk of LBW and preterm birth in infants born to women living in Los Angeles County, California between 1994 and 2000. Residential proximity to heavy traffic roadways was used as a surrogate measure of exposure to motor vehicle exhaust. The second research goal of this project was to evaluate whether maternal in-vehicle air pollutant exposures during commutes affected the risk of LBW and preterm birth in infants born to women living in Los Angeles County, California during 2003, who responded to a survey within 6 months of delivery (the EPOS study survey).

Summary of Findings:

Achievement of Project's Objectives/Accomplishments

First, we used an epidemiologic case-control study design to examine whether residential proximity to heavy-traffic roadways influenced the occurrence of LBW and/or preterm birth in Los Angeles County between 1994 and 1996 (Wilhelm and Ritz, 2003). We mapped subject home locations at birth and estimated exposure to traffic-related air pollution using a distance-weighted traffic density (DWTD) measure. This measure takes into account residential proximity to and level of traffic on roadways surrounding homes. We calculated odds ratios (ORs) and risk ratios (RRs) for being LBW and/or preterm per quintile of DWTD. The clearest exposure-response pattern was observed for preterm birth, with a RR of 1.08 (95% confidence interval [CI]=1.01–1.15) for infants in the highest DWTD quintile. Although higher risks were observed for LBW infants, exposure-response relations were less consistent. Examining the influence of season, we found elevated risks primarily for women whose third trimester fell during fall/winter months ($OR_{\text{term LBW}}$= 1.39; 95% CI=1.16–1.67; $OR_{\text{preterm and LBW}}$ = 1.24; 95% CI=1.03–1.48; $RR_{\text{all preterm}}$ = 1.15; 95% CI=1.05–1.26) and exposure-response relations were stronger for all outcomes for these women. This result is consistent with elevated pollution in proximity to sources during more stagnant air conditions present in winter months.

In a second study (Wilhelm and Ritz, 2004), we expanded our analysis to the time period 1994–2000 and incorporated available information on the number of trucks frequenting freeways in our study area. The number of trucks frequenting a given freeway may be important since some gasoline-fueled trucks emit more CO than passenger cars (on a per vehicle basis) and diesel-fueled trucks emit greater quantities of UF than passenger vehicles (Zhu, et al., 2002a,b). We mapped subject home locations at birth and estimated DWTD and the number of trucks on freeways within 750 feet of each residence. Although the California Department of Transportation (Caltrans) provides annual average daily traffic (AADT) values for roadway segments in LA County, these data do not differentiate between gasoline and diesel-fueled vehicles on regular streets. However, this agency does collect data on the number of trucks at various freeway locations throughout the state, listing the annual average number and percentages of 2-, 3-, 4-, and 5- or more axle trucks passing a given count location within a 24-hour period. Since a truck traffic count is not available for every freeway segment, the count data were extrapolated between count locations based on the postmile (i.e., location) and leg (i.e., direction) information provided in the truck count data. We used these data to determine the total number of trucks on freeways within 750 feet of subject residences. We also estimated the number of heavy-duty diesel trucks assuming 43% of the 2-axle (6 tire), 90% of the 3-axle and 100% of the 4-axle and 5 or more axle trucks were heavy-duty diesel. These percentages are based on truck census data reported by Dreher and Harley (1998). ORs for term LBW and preterm and LBW (preterm-LBW) birth, and RRs for preterm birth were estimated based on quintiles of the DWTD distribution and the 90th and 95th percentiles of the freeway truck distributions using logistic regression.

We did not observe associations between DWTD and LBW (term and preterm) for 1997–2000, but in certain subgroups we still observed associations with preterm birth: women whose third trimesters fell primarily during fall/winter months (November–April) (RR=1.07, 95% CI = 0.99–1.16, comparing the highest to lowest DWTD quintile) and women living in census block groups with a fraction of children in poverty at or above the median value (RR=1.08; 95% CI=1.00-1.18). However, we observed a 23% greater risk of preterm-LBW birth for women with ≥13,290 freeway trucks passing within 750 feet of their residence per day (95th percentile) (OR=1.23, 95% CI=1.06–1.43) during 1997–2000.

The limitations associated with using DWTD as a measure of motor vehicle exhaust exposure in pregnant women is discussed in Wilhelm and Ritz (2003). Previously we noted that the DWTD model assumes motor vehicle exhaust dispersion follows a Gaussian curve centered on a given roadway with 96% decay occurring at 500 feet (152.4 meters) and that such a curve may not adequately represent dispersion conditions since meteorologic factors such as wind direction, wind speed and inversion layer height may be important. We tried to address this issue in models that incorporated some simple adjustments for wind direction and wind speed. We accounted for the percentage of time each residence was downwind of a given street during certain pregnancy periods of interest, i.e., each home and street-specific DWTD value was weighted by one during hours when the home was downwind of the street and by zero during hours when the home was not downwind of the street. Residences were considered downwind of a street during hours when the wind direction was perpendicular to the street (in the downwind direction) ± 45 degrees. The pregnancy periods of interest were the third trimester for term LBW and six weeks prior to birth for preterm birth. These periods were selected based on our previous findings that showed the greatest associations between background air pollution and these adverse birth outcomes during these periods (Ritz and Yu, 1999 and Ritz, et al., 2000). After each home and street specific DWTD value was multiplied by the percentage of time downwind, these values were summed for all streets within the 750-ft buffer to obtain the final wind-direction adjusted DWTD value for each subject. In addition to incorporating wind direction into the DWTD measure, we also incorporated wind speed. Each home and street-specific DWTD value was multiplied by the percentage of time downwind and by 1/average wind speed during these downwind periods, i.e., we assumed a simple inverse relationship between concentrations of motor vehicle exhaust pollutants within 750 feet of the roadway and wind speed. Measurements of UF and CO near roadways indicate this assumption is reasonable for a simple modeling approach (Zhu, et al., 2002a,b; Benson, 1984). In general, these modifications of our original DWTD estimates did not change or improve the exposure-response patterns between DWTD and the outcomes.

In the work summarized above, we used electronic birth certificate data as the source of information on both health outcomes and other covariates we evaluated in our statistical models. However, the birth certificate data are missing information on some potentially important risk factors such as smoking, maternal stature and weight gain during pregnancy, and stress. We therefore conducted a nested case-control study in which we surveyed a sample of approximately 2,500 women in LA County (half of whom gave birth to a low weight or preterm infant) approximately four months after delivery to collect additional information on these factors (the survey was funded by the National Institute of Environmental Health Sciences [NIEHS]). As part of our survey, we asked women detailed information about their residential history and commuting habits during pregnancy. Of the 6,374 women sampled from the cohort of births during 2003, we conducted interviews with 2,544 women (response rate of 40%). Of these 2,544 women, 1,319 (52%) worked outside of the home during pregnancy. The median reported (one-way) commute length was 9 miles (range 0.1–100 miles) and 20 minutes (range 1–350 minutes) and 180 women (~14%) reported commuting 60 minutes or longer. Eighty percent of women reported commuting by car, 13% by bus, 1% by metro, and 5.5% by walking. One woman reported getting to work by bicycle and 6 reported some combination of methods (e.g., car and train, bus and train). We also collected information on moves during pregnancy and commuting times and lengths for each home, thus, these percentages are based on all homes and distances reported. We calculated an average commute length and time for each woman who worked outside the home during pregnancy, weighting the distance (in miles and minutes) for each home by the time during pregnancy spent in each home. Women who did not work outside the home were given a commuting distance and time of zero (thus in our analyses they were always in the referent group along with women with very short commuting lengths and times). We observed a 47% increase in risk of delivering a preterm and LBW infant and a 55% increase in risk of delivering a LBW infant at term for women who commuted 45 minutes or more compared to those who commuted 5 minutes or less (OR=1.47, 95% CI=0.97–2.24 and OR=1.55, 95% CI=0.98–2.43, respectively). Adjustment for a number of important covariates did not change these estimates substantially. Effect estimates were greater when comparing women who commuted 60 minutes or more to work than those who commuted 5 minutes or less (OR=1.48, 95% CI=0.88–2.50 and OR=1.74, 95% CI=1.00–3.00 for preterm and LBW and term LBW, respectively), although estimates were reduced by approximately 10% with adjustment for important covariates and confidence intervals were wider due to the small sample size.

Conclusions

We observed an approximately 10–20% increase in risk of preterm birth (both normal and low weight) and term LBW in infants born to women potentially exposed to high levels of traffic-related air pollution, as represented by DWTD when focusing on births during 1994–1996. These risks appeared to be strongest for women whose third trimester fell during fall/winter months, who lived in high background air pollution areas, and/or who lived in more impoverished areas according to census block-group level indicators of socioeconomic status (SES). Although residential proximity to traffic did not appear to be associated with higher risks of term LBW or preterm-LBW birth in the later time period included in this analysis (1997–2000), residential proximity to trucks on freeways did appear to be associated with greater risks of these outcomes, especially preterm-LBW, during 1997–2000. This suggests more heavily polluting vehicles within the overall cleaner motor vehicle fleet, such as trucks, may have become more important for these outcomes in the later years. Our finding of positive associations between ambient CO concentrations and term LBW, preterm-LBW birth, and preterm birth in 1997–2000 suggests, overall, air pollution may still be harmful. We feel a more refined exposure assessment approach is needed at this point to arrive at further conclusions concerning the associations between residential proximity to traffic and adverse birth outcomes we have seen in our studies. One approach would be to develop an individual exposure model that takes into account exposure to indoor sources of air pollution and in-vehicle exposures, in addition to residential exposures to outdoor air pollution by accounting for concentrations within each of these microenvironments and time-activity patterns of pregnant women. Measurements of key traffic-related pollutants (CO, NO_2, UF) inside a sample of Los Angeles homes with varying levels of traffic in close proximity would provide needed information about typical at-home exposures and the influence of indoor pollution sources to overall exposure. Our results also indicate that in-vehicle exposures to air pollution while commuting during pregnancy may be important for low birth weight. We plan to analyze these data further and take into consideration the importance of type of commute (e.g., car versus bus, freeway versus surface streets), whether commuting distances vary by pregnancy period and if yes, the importance of this variation to the outcomes of interest, the importance of car age, and the importance of total time spent in a car including other in-vehicle activities besides commuting to work.

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