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Low levels of ambient air pollution during pregnancy and fetal growth among term neonates in Brisbane, Australia

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Abstract

There is mounting evidence that maternal exposure to ambient air pollution during pregnancy is associated with adverse birth outcomes. We examined birth weight and small for gestational age (SGA <10th percentile for age and gender) among 26,617 singleton full-term births in Brisbane, Australia (July 2000–June 2003), in relation to ambient pollution during pregnancy. We also examined head circumference (HC) and crown–heel length (CHL) among a sub-sample ($n = 21{,}432$) of the term neonates. Maternal exposure to PM_{10}, visibility reducing particles (bsp), O_3 and NO_2 was assessed by calculating average exposure estimates over months and trimesters of pregnancy based on a citywide average of the pollutants. Linear and logistic regression models were employed to examine the effect of these pollutants on the birth outcomes after adjusting for potential confounders and season of birth. The regression coefficients were based on an inter-quartile range (IQR) increase in exposure as well as quartiles of exposure with the lowest used as a reference category. Trimester- and monthly specific exposures to all pollutants were not significantly associated with a reduction in either birth weight or HC, or an increased risk of SGA. An IQR increase in NO_2 during the third trimester was associated with a reduction in CHL ($\beta = -0.15$ cm, 95% CI -0.25 to -0.05 cm) and this was concentrated around exposure during month nine. No other pollutants were associated with a reduction in CHL. In conclusion, there was no strong evidence suggesting that ambient air pollution during pregnancy is associated with sub-optimal fetal growth in Brisbane.

Keywords: Air pollution; Pregnancy; Birth weight; Head circumference; Crown–heel length; Small for gestational age

1. Introduction

Over the past decade there has been mounting evidence that ambient air pollution during pregnancy influences fetal growth. Studies conducted in China (Wang et al., 1997), Korea (Ha et al., 2001; Lee et al., 2003), Taiwan (Yang et al., 2003), the Czech Republic (Bobak, 2000; Dejmek et al., 1999), Poland (Jedrychowski et al., 2004), Brazil (Gouveia et al., 2004), and North America (Chen et al., 2002; Liu et al., 2003; Maisonet et al., 2001; Parker et al., 2005; Ritz and Yu, 1999; Rogers et al., 2000; Vassilev et al., 2001) have reported an association between increased concentrations of ambient air pollution and sub-optimal fetal growth. However, there is inconsistency in the strength of the effect in relation to different pollutants and concentrations and the associated windows of exposure.

The majority of previous studies have been conducted in cities throughout the world where ambient air pollution levels are relatively high; however, a recent study in Sydney, Australia, found that lower concentrations of air pollutants were associated with sub-optimal fetal growth (Mannes et al., 2005). Ambient air pollution concentrations in Brisbane are similar to those in Sydney and recent time-series studies in Sydney (Morgan et al., 1998a,b) and Brisbane (Petroeschevsky et al., 2001; Simpson et al., 1997)

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found associations between ambient air pollution and increased hospital admissions and daily mortality. Therefore, the aim of this study was to investigate the relationship between ambient air pollution during pregnancy and various proxy measures of fetal growth among full-term neonates in Brisbane.

2. Materials and methods

2.1. Study population

Birth data for all singleton live births in Brisbane for the period of 1st July 2000–30th June 2003 were collected from the Queensland Health Perinatal Data Collection Unit. The main source of air pollution in Brisbane is vehicle emissions and therefore data pertaining only to neonates born to mothers who had resided within the Brisbane local government area (approximately a 20 km radius around the city) during pregnancy were obtained. The variables obtained from the database were date and method of delivery, birth weight, head circumference (HC), crown–heel length (CHL), neonate gender, gestational age (weeks), age of mother, number of previous pregnancies, number of previous abortions/miscarriages, marital status, indigenous status, number of antenatal visits, pre-pregnancy medical conditions, and an index of relative socio-economic disadvantage associated with the suburb of residency during pregnancy (index of SES). Due to ethical reasons, the date of the mother's last menstrual period (LMP) was not provided, therefore the date of the LMP was estimated by calculating back the number of weeks of gestation from the date of delivery. Neonates born to mothers with pre-pregnancy medical conditions such as diabetes, respiratory problems (e.g. asthma), epilepsy, cardiac problems, hypertension, and a previous stillbirth, and who had missing data on covariates were excluded from the sample. Finally, to control for gestational age, and to allow for exposure estimates across all nine months of pregnancy to be examined, the analyses were restricted to term neonates (completed 37 weeks of gestation).

Fetal growth was assessed by the proxy measures of birth weight, HC, CHL, and small for gestational age (SGA), which was defined as having a birth weight below the 10th percentile, by gestational age and gender, based on a sample of 761,902 Australian singleton live births between 1991 and 1994 (Roberts and Lancaster, 1999).

2.2. Air pollution and exposure assessment

Hourly readings for air pollutants were obtained from the Air Services Unit, Queensland Environmental Protection Agency, Queensland Government. The pollutants—ozone (O_3—reported as parts per billion (ppb)), nitrogen dioxide (NO_2—reported as ppb), particulate matter with an aerodynamic diameter $<10\,\mu m$ (PM_{10}—reported as micro grams per cubic metre ($\mu g/m^3$)), visibility reducing particles measured by nephelometry (bsp—reported as the inverse of mega metres (Mm^{-1}))—were used as a measure of fine particles due to limited availability of $PM_{2.5}$ data. Data for carbon monoxide (CO) and sulfur dioxide (SO_2) were limited for the study period and were therefore not examined. Hourly data were recorded at five monitoring stations across Brisbane for PM_{10} while hourly data for bsp, NO_2 and O_3 were recorded at four monitoring stations. Any day with less than 18 of 24 (75%) possible hours of available readings was considered as a day with missing data. To fill in the small number of missing days an estimate was calculated using seasonal averages from both the site with the missing data and the site/s without the missing data for that day. A daily average (24-h average) was calculated from the original hourly data for PM_{10}, bsp, and NO_2, and an 8-h average was calculated for O_3 (daily maximum calculated from an 8-h moving average).

Trimester- and monthly specific exposure estimates for each pollutant were calculated as the mean of the daily values within the trimesters and months (nine 30-day periods) of pregnancy starting from the date of the LMP for each mother/neonate pair. The exposure estimates were based on a citywide average of the available monitoring stations.

2.3. Statistical analysis

Multiple logistic regression models were employed to calculate odds ratios (OR) and 95% confidence intervals (CI) for SGA while linear regression models were employed to examine the change in the mean birth weight, HC, and CHL. The maternal exposure estimates were first entered into the regression models as a continuous measure with the regression coefficients based on an inter-quartile range (IQR) increase. To assess any exposure–response relationships the maternal exposure estimates were also categorised into quartiles, which were entered into the models as indicator variables with the lowest used as a reference category. To assess for a trend across the quartiles they were also entered into the models as a quantitative variable (coded 1–4). Based on an 'a priori' approach, the explanatory variables included in the multivariable models were neonate gender, gestational age (with a quadratic term due to the curve linear relationship with birth weight, HC and CHL), age of mother, parity, number of previous abortions/miscarriages (nil, 1, 2 or more) marital status (married, single, other), indigenous status (yes/no), number of antenatal visits (8 or more, 5–7, <4), type of delivery (spontaneous/caesarean/assisted), an index of SES (in quintiles). All available explanatory variables were significant in the multivariable models (note that models examining term SGA excluded gestational age and neonate gender), except mother's age, which was not associated with CHL—however, this was kept in the model.

Despite season of birth having no significant association with birth weight, SGA, and CHL, and only a weak association with HC, in order to control for seasonal influences, season of birth was also entered into all models with summer as the reference category. All analyses were performed using SAS version 8.2 (SAS Institute Inc., Cary, NC, USA).

3. Results

There were 31,307 births in the Brisbane local government area during the study period and of these there were 28,225 eligible for inclusion into the sample. There were 25 births subsequently excluded due to missing data for covariates, which then left 28,200 in the sample. Within this sample there were 26,617 term births used in the final analyses where the gestational ages ranged from 37 to 44 weeks. All 26,617 term neonates had complete data for birth weight while 21,432 had complete data for both HC and CHL. The mean birth weight was 3498 g (SD = 463 g, min = 1340 g, max = 6100 g) while the mean HC was 34.9 cm (SD = 1.4, min = 24.5, max = 41.0) and the mean CHL was 51.4 cm (SD = 2.4, min = 35.0, max = 69.0). Of the 26,617 neonates, 1890 (7.1%) were classified as SGA.

The concentrations of air pollutants during the study period are shown in Table 1. Correlation coefficients between the four monitoring stations that monitored bsp, O_3, and NO_2 ranged from 0.58 to 0.76 for bsp; from 0.54 to 0.83 for O_3; and from 0.54 to 0.75 for NO_2. Correlation coefficients between the five monitoring stations that monitored PM_{10} ranged from 0.80 to 0.93. All pollutants were seasonal with NO_2 showing the strongest pattern with a peak in winter and nadir in summer. The seasonal pattern was not as strong for bsp and PM_{10} with a peak in winter carrying on into spring. The O_3 concentrations showed a peak during spring and nadir during autumn/winter.