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Exposure to low concentrations of air pollutants and adverse birth outcomes in Brisbane, Australia, 2003–2013☆

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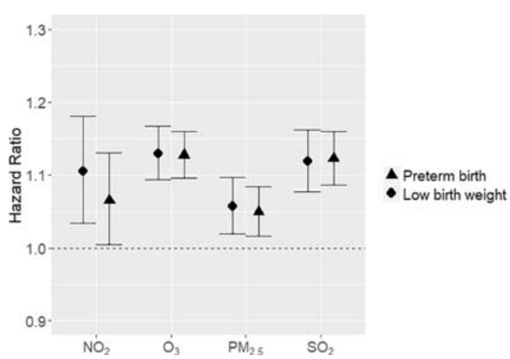
HIGHLIGHTS

- Low-level air pollution during pregnancy induced preterm birth and low birth weight.
- Highest risks were observed during trimester 3, and lowest in trimester 1.
- Stronger effects were present for exposure to cold and moderate temperatures.

GRAPHICAL ABSTRACT



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ABSTRACT

Background: It's unclear whether exposures to low-level air pollution have adverse effects on birth outcomes, and which trimester-specific pregnant exposure is sensitive.
Objectives: To investigate the effects of maternal exposure during each trimester and the whole pregnancy to particles with aerodynamic diameter < 2.5 μm ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3) on preterm birth (PTB) and low birth weight (LBW).
Methods: Daily data on birth records, air quality, and weather conditions were collected in Brisbane, Australia during 2003–2013. Mean concentrations of air pollutants were calculated for each trimester of pregnancy. Cox proportional hazards models were used to examine the associations between air pollution and birth outcomes. Multi-pollutant models and stratified analyses by ambient temperature were performed.
Results: Exposures to $PM_{2.5}$, SO_2, NO_2, and O_3 during the whole pregnancy were associated with increased risk of PTB [IQR HRs (hazard ratios with an interquartile range increase in air pollutants) and 95% confidence intervals (CIs): 1.05 (1.02, 1.08), 1.12 (1.09, 1.16), 1.07 (1.01, 1.13), and 1.13 (1.10, 1.16), respectively] and LBW [IQR HRs and 95% CIs: 1.06 (1.02, 1.10), 1.12 (1.08, 1.16), 1.11 (1.03, 1.18), and 1.13 (1.09, 1.17), respectively]. Highest HRs were observed during trimester 3, and lowest in trimester 1. For each air pollutant, stronger effects on PTB and LBW were present for exposure to low and moderate temperatures than exposure to high ambient temperature.
Conclusions: Exposures to low-level air pollutants are related to adverse birth outcomes. More effective policies for air quality control could contribute to improving neonatal health.

☆ Capsule: Exposures to low-level air pollutants are related to preterm birth and low birth weight
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1. Introduction

Preterm birth (PTB) and low birth weight (LBW) are important neonatal health problems that account for 11.1% and 15.5% of all newborns worldwide in 2010 and 2004, respectively (Blencowe et al., 2012; Wardlaw, 2004). Although survival of these babies has substantially improved, they remain at risk of a wide range of complications and sequelae during their childhood and adulthood (Franco et al., 2006; Saigal and Doyle, 2008; Vohr et al., 2000). PTB and LBW are multi-cause birth outcomes for which the mechanisms are complex and have not been fully explained (De Bernabé et al., 2004; Goldenberg et al., 2008). Numerous studies have reported environmental risk factors for PTB and LBW, among which, ambient air pollution is of increasing public concern (Li et al., 2017; Stieb et al., 2012; Sun et al., 2016).

Despite the standards for air quality established in many regions of the world, previous study indicated no threshold level for health effects of air pollution (Schwartz et al., 2002). Understanding the health effects of low-level air pollution helps to make effective policies to improve public health, especially for susceptible population including fetuses and pregnant women (Makri and Stilianakis, 2008). Air pollution exposure during pregnancy could be transferred to fetus through placenta from mother that has effects on fetal development (Kampa and Castanas, 2008). Due to rapid proliferation of cells and limited capacity of metabolism, the developing organs and systems of the fetus are particularly susceptible to air pollutants (Šrám et al., 2005). Previous studies have reported adverse birth outcomes associated with air pollution in regions with low-level air pollution, e.g., Canada and Europe (Dugandzic et al., 2006; Jedrychowski et al., 2004; Madsen et al., 2010). However, their findings were inconsistent and the effects of air pollution at different stages of pregnancy (early, mid, and late pregnancy) have seldom been previously evaluated (Lee et al., 2003). Although the effects of ambient air pollution on birth outcomes have been previous investigated in Australia (Barnett et al., 2011; Hansen et al., 2006; Hansen et al., 2007; Hansen et al., 2008), incidences of birth outcomes and antenatal care may have changed in recent years (Blencowe et al., 2012; Brown et al., 2014).

In this study, birth records and daily data on air quality and weather conditions were collected in Brisbane, Australia, during 2003–2013. The effects of maternal exposure to four air pollutants on PTB and LBW during each trimester of pregnancy and the whole pregnancy were evaluated and compared.

2. Method and materials

2.1. Study area

Brisbane is the third most populated city in Australia located in South East Queensland. Its metropolitan area has a population of 2.4 million. Brisbane is characterized with humid subtropical climate and has low level of air pollution (annual mean concentrations of air pollutants under WHO guideline values) (WHO, 2014). The annual mean concentrations of particles with aerodynamic diameter < 2.5 μm ($PM_{2.5}$) and particles with aerodynamic diameter < 10 μm (PM_{10}) are 6 μg/m^3 and 16 μg/m^3, respectively (http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/).

2.2. Birth records and maternal information

Birth records and maternal information in the Brisbane metropolitan area of Australia (1st July 2003–31th December 2013) were obtained from Queensland Health Perinatal Data Collection Unit (https://www.health.qld.gov.au/hsu/collections/pdc). These included birth records identified by all public and private hospitals and voluntarily reported homebirths. Details of birth data used in this study were previously reported (Li et al., 2016). Continuous variables used in this study were maternal age (years), gestational age (weeks), and birth weight (grams). Categorical variables included baby gender (male or female), number of births (1 or >1), previous pregnancy (yes or no), medical conditions during pregnancy (yes or no), and smoking status during pregnancy (smoker or non-smoker). PTB was defined as any birth with <37 completed weeks of gestational age and LBW was defined as weight at birth <2500 g (Blencowe et al., 2012; Wardlaw, 2004). The study protocol was approved by The University of Queensland Human Research Ethics Committee.

2.3. Air quality and meteorological data

Air quality and meteorological data during the study period were obtained from Queensland Department of Environment and Heritage Protection (https://www.ehp.qld.gov.au/). Data in 2002 were also collected to account for pregnancies leading to births in 2003. Details on the measurements were previously reported (Li et al., 2016). Briefly, hourly concentrations of four air pollutants, $PM_{2.5}$, sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3), were monitored by five fixed monitoring sites in the metropolitan area of Brisbane. $PM_{2.5}$ was sampled with high and low volume air samplers or monitored with a Tapered Element Oscillating Microbalance (TEOM) method. SO_2, NO_2 and O_3 were measured using Differential Optical Absorbance Spectroscopy (DOAS) instruments. Hourly concentrations of pollutants were converted into daily averages in this study. Daily mean temperature (°C) and relative humidity (%) were also collected. To evaluate the effects of air pollution on birth outcomes at each stage of pregnancy, average levels of each air pollutant and meteorological variable were calculated for all participants during each trimester of pregnancy (trimester 1: 0–12 weeks, trimester 2: 13–28 weeks, trimester 3: after 28 weeks), as well as the whole pregnancy. The first day of exposure was defined as the first day of last menstrual period in this study.

2.4. Statistical analysis

As pregnant women with different gestational ages may have different length of exposing periods, to take into account both birth outcomes and the exposure time, the associations between mean concentrations of air pollutants at each stage of pregnancy and birth outcomes were examined using Cox proportional hazards regression models (Strand et al., 2011; Wang et al., 2013). The mean concentrations of air pollutants during each stage of pregnancy (three trimesters and the whole pregnancy) were calculated for each participant to represent her trimester-specific exposures to air pollution. Particularly, participants who gave birth before or at 28 gestational weeks were excluded in the analyses for trimester 3. Considering the non-linear effects of meteorological variables, mean ambient temperature and relative humidity during the same period as the air pollution data were included with natural cubic splines of 3 degrees of freedom (Guo et al., 2011; Strand et al., 2011). Apart from air pollution and meteorological variables, other co-variates were also controlled in the models including: maternal age, baby gender, number of births, previous pregnancy, medical conditions during pregnancy, and maternal smoking status. Models were developed for each outcome (PTB and LBW) and each stage of pregnancy (three trimesters and the whole pregnancy), respectively. Survival time was defined as the duration from the first day of last menstrual period to the date of birth. In addition, both single-pollutant and multi-pollutant models were developed. To examine the potential modification effects of ambient temperature, stratified analyses were performed by low, moderate and high temperatures (divided by tertiles of mean ambient temperature during the whole pregnancy). In this study, the effects of air pollution on birth outcomes were expressed as hazard ratios (HRs) and 95% confidence intervals (95% CI) associated with an interquartile range (IQR) increase in each air pollutant.