Environment International 119 (2018) 407–412

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Exposure to ambient fine particulate matter during pregnancy and gestational weight gain

Jiaqiang Liao[a,1], Huifang Yu[a,1], Wei Xia[a], Bin Zhang[b], Bin Lu[a], Zhongqiang Cao[b], Shengwen Liang[c], Ke Hu[c], Shunqing Xu[a], Yuanyuan Li[a,*]

[a] Key Laboratory of Environment and Health, Ministry of Education & Ministry of Environmental Protection, State Key Laboratory of Environmental Health, School of Public Health, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, People's Republic of China

[b] Wuhan Children's Hospital (Wuhan Maternal and Child Healthcare Hospital), Tongji Medical Collegec, Huazhong University of Science and Technology, Wuhan, Hubei, People's Republic of China

[c] Wuhan Environmental Monitoring Center, Wuhan, Hubei Province 430000, People's Republic of China

ARTICLE INFO

Keywords:
Ambient air pollution
PM2.5
Exposure during pregnancy
Gestational weight gain

ABSTRACT

Background: Gestational weight gain (GWG) is increasingly reported to be associated with adverse birth outcomes. However, the effect of $PM_{2.5}$ exposure during pregnancy on GWG is unknown.

Objectives: We investigated the associations between the exposure to $PM_{2.5}$ and GWGs during three pregnancy trimesters based on a prospective birth cohort.

Methods: Data were obtained from 2029 pregnant women who participated in a birth cohort between January 2013 and October 2014 in Wuhan, China. A spatial-temporal land use regression model was used to estimate the trimester and overall pregnancy exposures of $PM_{2.5}$ of each pregnant woman. The relationships between $PM_{2.5}$ exposure and GWG were estimated using linear mixed models.

Results: The median value of GWG was 2.0 kg (interquartile range (IQR): 4.0) in the first trimester, 6.5 kg (IQR: 3.5) in the second trimester, and 7.0 kg (IQR: 3.5) in the third trimester, respectively. The exposure to $PM_{2.5}$ was peaked in the first trimester (median concentration: 117.3 μg/m^3 (IQR: 71.9)). After adjustment for potential confounders, each 10 μg/m^3 increase in $PM_{2.5}$ was consistently associated with increases in GWG in overall pregnancy (0.14 kg, 95% confidence interval (*CI*): 0.12, 0.17), the first (0.15 kg, 95%*CI*: 0.12, 0.18), second (0.15 kg, 95%*CI*: 0.10, 0.19) and third trimester (0.13 kg, 95%*CI*: 0.09, 0.17). Further stratified analysis indicated that pregnant women who delivered in spring or summer gained more body weight associated with $PM_{2.5}$ exposure.

Conclusions: This study provides evidence on the effect of exposure to $PM_{2.5}$ on GWG and it is the first report on the importance of reducing the ambient $PM_{2.5}$ in controlling of GWG in pregnant women.

1. Introduction

Excessive or inadequate gestational weight gain (GWG) are increasingly reported to be associated with elevated risk of adverse birth outcomes. Pregnant women with excessive GWG are more likely to have hypertensive disorder (Barton et al., 2015; Ferraro et al., 2015) and gestational diabetes mellitus (Sorbye et al., 2017) and give macrosomia infants or infants with large for gestational age (Bodnar et al., 2010; Ludwig and Currie, 2011). Excessive GWG also has a long-term health impact on children, especially in terms of obesity (Gaillard et al., 2013) and cerebrovascular disease (Bhattacharya et al., 2016), while the inadequate GWG are reported to be associated with infant's death, small for gestational age and preterm birth (Fujiwara et al., 2014; Pettit et al., 2015).

The International Organization of Medicine (IOM) has built a worldwide GWG recommendation by balancing risks associated with excessive or inadequate GWG. According to this recommendation, the optimal GWG is suggested within 12.5 to 18, 11.5 to 16, 7 to 11.5, and 5 to 9 kg for pregnant women who were underweight, normal weight, overweight, and obese during pre-pregnancy. However, most of the pregnant women had excessive GWG according to this recommendation (Truong et al., 2015).The causes of the excessive GWG have been shown

* Corresponding author at: School of Public Health, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430030, People's Republic of China.

E-mail address: liyuanyuan@hust.edu.cn (Y. Li).

[1] Both authors equally contributed to this article.

https://doi.org/10.1016/j.envint.2018.07.009
Received 30 April 2018; Received in revised form 27 June 2018; Accepted 6 July 2018
0160-4120/

to be multifactorial. Numerous studies reported that excessive food intake, nightly sleep duration, smoking during pregnancy, and reduction of physical activity were associated with increased GWG (Heery et al., 2015; Restall et al., 2014; Shin et al., 2014). It is noteworthy that environmental factors may also have an important role in the increase of GWG. Animal studies observed that high air particle matter concentrations resulted in increased GWG in rats (Wei et al., 2016). A recent study reported that higher $PM_{2.5}$ concentrations were associated with increased risk of obesity in an adult population(Mazidi and Speakman, 2017), and other studies also demonstrated that exposure to $PM_{2.5}$ was associated with increased risks of childhood overweight or obesity (Jerrett et al., 2014; Li et al., 2016; Mao et al., 2017). However, to the best of our knowledge, no studies have addressed the association between $PM_{2.5}$ exposure and GWG in pregnant women.

In this study, we examined the association between exposure to $PM_{2.5}$ during pregnancy and GWG in a birth cohort. We longitudinally followed the GWGs in the first, second, and third trimesters and analyzed associations of $PM_{2.5}$ exposure with GWGs during different trimesters.

2. Population and methods

2.1. Study population

The study population was from a birth cohort study in Wuhan city, China. Pregnant women who came to the Women and Children Healthcare Centre of Wuhan for the first prenatal examination during January 2013 to October 2014 were invited to participate in the birth cohort. To be eligible, pregnant women should reside in Wuhan city above one year and agree to have in-person interviews, as well as have prenatal examinations in time periods prescribed. The research protocol was approved by the ethics committee of the Tongji Medical College, Huazhong University of Science and Technology. Each participant provided signed informed consent at enrolment.

We restricted our analysis to the women who gave births to live singletons and had the completed measurements of trimester GWGs ($n = 2039$). To make our conclusions more representative to the general pregnant women, we further excluded pregnant women who delivered infants with birth defects ($n = 7$) and pregnant women who had missing information on maternal education ($n = 3$). Finally, 2029 pregnant women were included in our analysis.

2.2. Assessment of exposure to ambient $PM_{2.5}$

We obtained data of 10 national environmental routine monitoring stations representing the daily average concentration of $PM_{2.5}$ over the Wuhan city from the Wuhan Environmental Monitoring Center. The residential home addresses of pregnant women were collected by a questionnaire investigation and were geocoded using ArcGIS 9.3.

We constructed a remote sensing data at a 30 km ∗ 30 km resolution in Wuhan based on Landsat-7 Enhanced Thematic Mapper-Plus ETM+ data which was distributed by the U.S Landsat Science (https://landsat.gsfc.nasa.gov/landsat-7/). We used ArcGIS 9.3 software with image analysis tool to abstract the areas of land use (commercial and industrial land, farmland, forest, lake, and river) from 2013 to 2014 in Wuhan. We calculated the areas of land use within different circular buffers with a radius of 1 km, 5 km, 10 km, 15 km and 20 km around each monitoring site and each prenatal residential home address. Digital road network data in Wuhan was obtained from the National Geomatics Center of China. We included road types of national level, county level and street level which were reported to be associated with traffic-related air pollution. We calculated two types of road-related predictor variables: distance to the nearest road and road length within a circular buffer of 1 km and 5 km. Enterprises associated with air pollution were obtained from the online surveillance system supported by Wuhan Environmental Protection Agency. We geocoded the addresses of these enterprises and calculated the industry-related predictor variables (numbers of enterprises within a circular buffer of 1 km and 5 km and distance to the nearest enterprise). We obtained 7 national routine monitoring weather stations within or nearby Wuhan city from the Chinese Meteorological Bureau. Each weather station recorded daily average temperature, cumulative rainfall from 20 to 20 h, average relative humidity, duration of sunshine, and average wind speed. The pregnant women's daily exposures to weather variables were interpolated using an inverse distance weighting method.

We used a spatial-temporal land use regression (LUR) model with short-term (week) and long-term (season) variations adjustment by using non-linear terms of natural cubic splines with 12× 4 knots in each year to evaluate the residential daily $PM_{2.5}$ exposure in pregnant women. We firstly included predictor variables in spatial-temporal LUR models if they (1) altered the main R^2 by > 1%; and (2) did not cause the severity of co-linearity (predictors with variance inflation factor (VIF < 3). We finally used a leave-one-out cross-validation (LOOCV) method to evaluate the performance of the spatial-temporal LUR model. Data from one station was left out as validation data set, and data from remaining N-1 stations were used as training set. The R^2 between the predicted value and the observed $PM_{2.5}$ concentrations was calculated, and the results indicated that the spatial-temporal LUR model had a good variability to predict daily $PM_{2.5}$ concentrations in our targeted population (the averaged model explained variance $R^2 = 87.2\%$).

Daily estimated $PM_{2.5}$ concentrations from the conception to the gestational 13th week, the gestational 14th week to 27th week, and the gestational 28th week to delivery were averaged to assess $PM_{2.5}$ exposures in the first, second and third trimester.

2.3. Outcome

The outcome of this study was trimester GWGs. Trimester GWGs were calculated by the difference between the pregnant women's body weight recorded at gestational weeks of 13 (mean ± standardized deviation (SD): 13 ± 1.0; range: 12–14), 27 (mean ± SD: 27 ± 1.0; range: 26–28), and 36 (mean ± SD: 36 ± 1.0; range: 35–37) and prepregnancy body weight, which was self-reported at the first prenatal visit. Body weight during pregnancy was measured using a standard digital scale in the study hospital and pregnant women were asked to take off the shoes and coats during the measurements.

2.4. Covariates

Face to face interviews by trained nurses were conducted within three days before or after delivery to collect information on socio-demographic and lifestyle characteristics such as maternal education, passive smoking, and physical activity during pregnancy. Information on the date of last menstrual period (LMP), the date of delivery, disease history of gestational hypertension and gestational diabetes were obtained from medical records. Gestational age (weeks) was calculated as the date of delivery minus the date of LMP.

2.5. Statistical analysis

We fitted linear mixed models with a random intercept to estimate the association between $PM_{2.5}$ exposure and GWG over the course of pregnancy, to allow for random effect at pregnant women level. To estimate the trimester associations between trimester exposures of $PM_{2.5}$ and trimester GWGs, we added a multiplicative interaction term between the continuous measurement of $PM_{2.5}$ exposure and trimesters in the linear mixed models.

We used a Directed Acyclic Graphs (DAG) method to determine the potential confounders in our multiple adjusted analyses. The full model by DAG was based on a Six-Step Process(Shrier and Platt, 2008) which resulted in adjustment for: gestational age at birth (weeks), maternal age at recruitment (≤24, 25–29, 30–34, and ≥35 years), parity