Environment International 94 (2016) 591–599

Contents lists available at ScienceDirect

Environment International

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

Particulate matter and early childhood body weight

Eunjeong Kim [a], Hyesook Park [b], Eun Ae Park [c], Yun-Chul Hong [d], Mina Ha [e], Hwan-Cheol Kim [f], Eun-Hee Ha [g,*]

[a] Department of Occupational and Environmental Medicine, Ewha Womans University Mokdong Hospital, Seoul, South Korea
[b] Department of Preventive Medicine and Ewha Medical Research Center, School of Medicine, Ewha Womans University, Seoul, South Korea
[c] Department of Pediatrics, School of Medicine, Ewha Womans University, Seoul, South Korea
[d] Department of Preventive Medicine, College of Medicine, Seoul National University College of Medicine, Seoul, South Korea
[e] Department of Preventive Medicine, College of Medicine, Dankook University, Cheonan, South Korea
[f] Department of Occupational & Environmental Medicine, Inha University School of Medicine, Incheon, South Korea
[g] Department of Occupational and Environmental Medicine, Ewha Medical Research Center, School of Medicine, Ewha Womans University, Seoul, South Korea

ARTICLE INFO

Article history:
Received 19 January 2016
Received in revised form 16 June 2016
Accepted 16 June 2016
Available online 22 June 2016

Keywords:
Air pollution
Particulate matter
Children growth
Weight

ABSTRACT

Concerns over adverse effects of air pollution on children's health have been rapidly rising. However, the effects of air pollution on childhood growth remain to be poorly studied. We investigated the association between prenatal and postnatal exposure to PM10 and children's weight from birth to 60 months of age. This birth cohort study evaluated 1129 mother-child pairs in South Korea. Children's weight was measured at birth and at six, 12, 24, 36, and 60 months. The average levels of children's exposure to particulate matter up to 10 μm in diameter (PM10) were estimated during pregnancy and during the period between each visit until 60 months of age. Exposure to PM10 during pregnancy lowered children's weight at 12 months. PM10 exposure from seven to 12 months negatively affected weight at 12, 36, and 60 months. Repeated measures of PM10 and weight from 12 to 60 months revealed a negative association between postnatal exposure to PM10 and children's weight. Children continuously exposed to a high level of PM10 (>50 μg/m^3) from pregnancy to 24 months of age had weight *z*-scores of 60 that were 0.44 times lower than in children constantly exposed to a lower level of PM10 (≤50 μg/m^3) for the same period. Furthermore, growth was more vulnerable to PM10 exposure in children with birth weight <3.3 kg than in children with birth weight >3.3 kg. Air pollution may delay growth in early childhood and exposure to air pollution may be more harmful to children when their birth weight is low.
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1. Introduction

Ambient air pollution is considered as an unavoidable environmental exposure and serves as a source of oxidative stress and inflammation inducing factors with effects on cardiovascular and pulmonary systems (Brook et al., 2010; Götschi et al., 2008; Perez et al., 2010). Children are especially vulnerable to air pollution because their respiratory and immune systems are immature and are at the stage of rapid development (Landrigan and Etzel, 2014). Air pollution increases infant mortality and is related to risks of respiratory infection, asthma, and low respiratory function (Landrigan and Etzel, 2014). Furthermore, exposure to air pollutants during pregnancy has been related to adverse birth outcomes, including preterm birth and low birth weight, as well as other health problems (Kim et al., 2014; Osmond and Barker, 2000; Pope et al., 2010; Srám et al., 2005).

A wide spectrum of birth weight and growth patterns occurs during childhood. Low birth weight has been associated with cardiovascular and metabolic diseases in subsequent adulthood (Osmond and Barker, 2000). Growth restriction in utero can sometimes result in accelerated growth above the normal range for at least 1 year of age, which later leads to catch-up growth (Finkielstain et al., 2013; Wit and Boersma, 2002). Variations in growth patterns in early childhood can therefore affect health and development later in life. For example, rapid catch-up weight gain after birth has been linked with obesity and high blood pressure (Lei et al., 2015; Ong and Loos, 2006; Salgin et al., 2015). On the contrary, a failure in catch-up growth in early childhood has been associated with low intelligence (Lei et al., 2015). Postnatal growth restriction and subsequent catch-up growth may also reduce insulin sensitivity (Alexeev et al., 2015). Children with low birth weight also might have more varied growth patterns than the patterns seen in children with normal birth status. Children with low birth weight can also be more vulnerable to environmental hazards than other children; therefore, more studies should be conducted with respect to low birth weight population (Fleisch et al., 2015; Lei et al., 2015).

Abbreviations: PM10, particulate matter up to 10 μm in diameter; IDW, inverse distance weighting; MOCEH study, Mothers and Children's Environmental Health study; BMI, body mass index; GLM, generalized linear model; GEE, generalized estimating equations.

* Corresponding author at: Department of Occupational and Environmental Medicine, Ewha Medical Research Center, School of Medicine, 911-1 Mok-5 dong, Yangcheon-ku, Seoul 158-056, Korea.

E-mail address: eunheeha@ewha.ac.kr (E.-H. Ha).

http://dx.doi.org/10.1016/j.envint.2016.06.021
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Some evidences support an association between prenatal exposure to air pollution and birth outcomes, including birth weight, but the relationship between air pollution and children's growth is still unclear. Furthermore, numerous studies have measured only prenatal exposure to air pollution in an effort to investigate the relationship between both the issues or to perform a comparative analysis between the groups living in areas with different levels of exposure (Ghosh et al., 2011; Jerrett et al., 2010; Sram et al., 2013; Tielsch et al., 2009). In other words, previous studies either carried out observations only during a certain period of time or failed to measure individual exposure levels to air pollution to identify association between air pollution and growth in children.

The aim of this study was to investigate the association between prenatal and postnatal exposure to air pollution and children's weight at the time of birth and at six, 12, 24, 36, and 60 months with repeated measures of individual exposure level of particulate matter up to 10 μm in diameter (PM10). We used a longitudinal study with repeated measures of exposure level for air pollution and child growth at each follow-up to provide an opportunity to understand the relationship and to reveal the periods of susceptibility to air pollution exposure in child growth. We also investigated whether children's birth weight might have impact on the vulnerability to air pollution by comparing the impact of PM10 exposure on child growth in two groups of children (lower birth weight and higher birth weight than the mean birth weight).

2. Methods

2.1. Study population

This research was conducted as a part of the Mothers and Children's Environmental Health (MOCEH) study, a multiregional prospective birth cohort study in South Korea established in 2006 to investigate the effects of environmental hazards on the health of mothers and their children. The regional centers of the study (Seoul, Cheonan, and Ulsan) each feature a community-based network of a university hospital, local clinics, and public health centers. Pregnant women from these cities and who fulfilled the inclusion criterion of being >18 years of age were enrolled before they were into 20 weeks of their pregnancies. All enrolled participants provided written informed consent at the initial visit. The study protocols and design were approved by the Institutional Review Boards of Ewha Womans University, Dankook University Hospital, and Ulsan University Hospital (Kim et al., 2009).

Among the 1751 enrolled participants in this study, exposure levels of PM10 were estimated for 1484 mother–child pairs, who provided all required information for the exposure modeling method, including residential address and birth date. Of these 1484 pairs, 1454 remained after excluding children for whom growth measurements were not assessed at the time of birth and at six, 12, 24, 36, and 60 months visits. Children with birth weight <2500 g or preterm births at gestational ages under 37 weeks ($n = 79$) were excluded from this study with regard to other considerable health determinants or problematic conditions, such as birth defects and maternal malnutrition; furthermore, it was assumed that other health complications from adverse birth condition might have confounded the results of the association between PM10 and child growth follow-up. Table S1 shows weight distribution for the babies excluded from the study because of low birth weight (birth weight <2500 g) and preterm birth. An analysis of the association between prenatal PM10 exposure and adverse birth outcomes revealed no significant relationship between prenatal PM10 exposure and preterm birth, small for gestational age, or low birth weight (Table S2).

Another 246 mother-infant pairs were excluded from the study because of missing covariates data. Ultimately, 1129 mother-child pairs were included in the analysis. However, some children were lost for follow-up or missed measurements at some visits, so the number of children included in the association analysis was 1129 at birth, and 812, 728, 648, 545, and 387 at 6, 12, 24, 36, and 60 months, respectively (Fig. 1).

At the time of enrolment, the sociodemographic covariates of maternal age, maternal education, and family income were collected, the body mass index (BMI) was calculated based on maternal pre-pregnancy weight and height, and cotinine levels in urine was measured. Data on pregnancy health results, such as hypertension or diabetes during pregnancy, and weight gain during pregnancy were collected at delivery, and birth outcomes, such as birth weight, sex, and gestational age, were obtained from perinatal medical records. At the time of six month visit, information about the feeding method of infants was obtained.

The variables in the model were categorized and used as categorical variables, except for maternal pre-pregnancy BMI, gestational age, maternal age, and maternal weight gain during pregnancy, which were used as continuous variables. Maternal cotinine levels in urine were categorized by 95 percentiles of the total level, which was 14.9 μg/g creatinine. Children were divided into two groups with a cut-off point of mean birth weight (3.3 kg) in this study and were examined for weight growth until 60 months of age to investigate whether vulnerability to

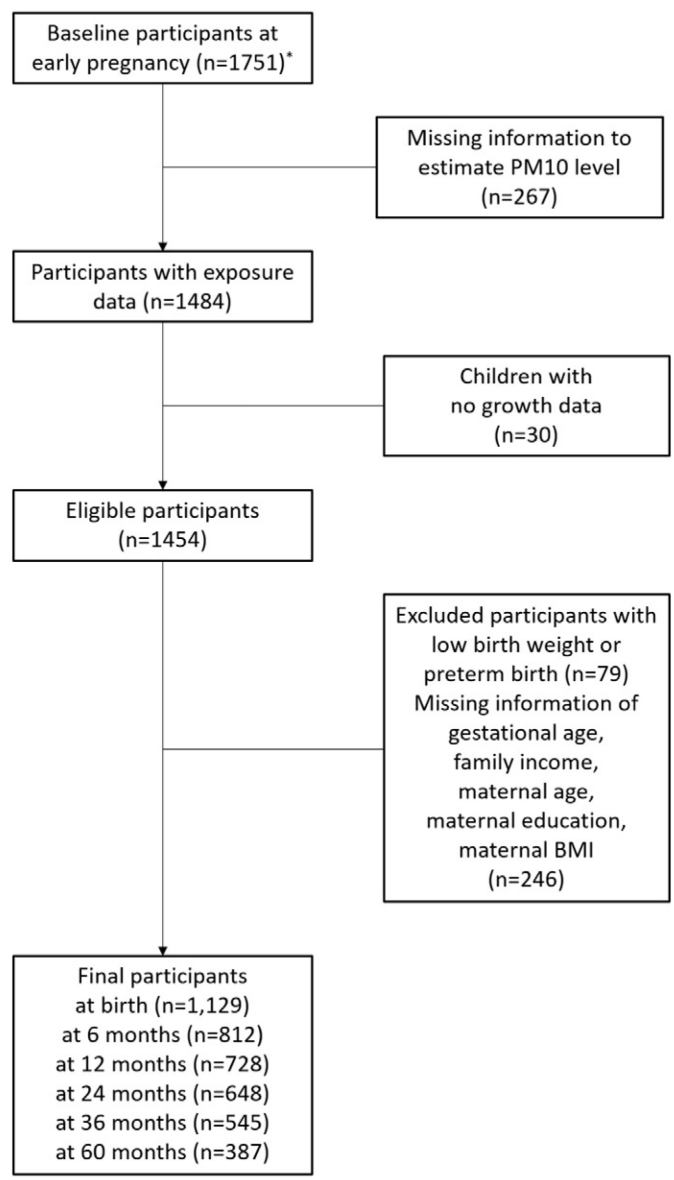

Fig. 1. Flow chart of the study population. *Total number of enrolled mother–child pairs in the MOCEH study.

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