Science of the Total Environment 584–585 (2017) 72–77

Contents lists available at ScienceDirect

Science of the Total Environment

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

Timing of an accelerated body mass increase in children exposed to lead in early life: A longitudinal study

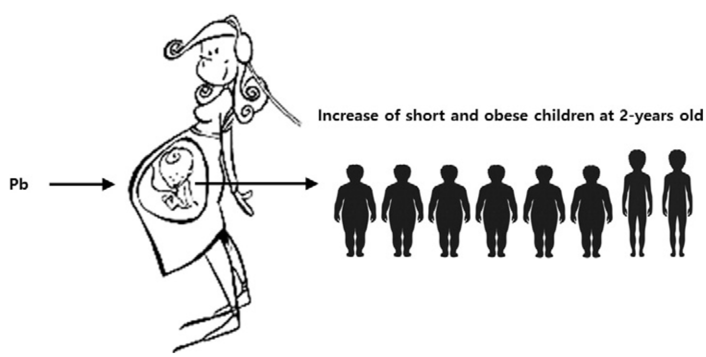
Jin Hee Kim [a,b], Yelim Park [c], Sung Koo Kim [d], Hyo-Bang Moon [e], Jeongim Park [c], Kyungho Choi [a,f], Sungkyoon Kim [a,f,*]

[a] Department of Environmental Health Sciences, Graduate School of Public Health, Seoul National University, Seoul, Republic of Korea
[b] Department of Integrative Bioscience & Biotechnology, Sejong University, Seoul, Republic of Korea
[c] College of Natural Sciences, Soonchunhyang University, Asan, Republic of Korea
[d] College of Medicine, Hallym University, Seoul, Republic of Korea
[e] Department of Marine Sciences and Convergent Technology, Hanyang University, Ansan, Republic of Korea
[f] Institute of Health and Environment, Graduate School of Public Health, Seoul National University, Seoul, Republic of Korea

HIGHLIGHTS

- Obesity in early life might be important in development of obesity-related diseases.
- Perinatal lead exposure accelerated body mass increase in 2-years old children.
- Efforts in reducing lead exposure in early life should be considered.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 26 September 2016
Received in revised form 18 January 2017
Accepted 18 January 2017
Available online 20 February 2017

Editor: D. Barcelo

Keywords:
Lead
Perinatal exposure

ABSTRACT

In utero exposure to lead is known to cause various adverse health outcomes and early life obesity can affect permanent metabolic alterations leading to adverse health outcomes. To examine the relation between perinatal lead exposure and childhood obesity, lead level in cord bloods and growth- and obesity-related markers at birth were measured from 280 mother-child pairs. The weight, height, and body mass index (BMI) of children were measured at birth and followed up several times up to 27 months of age. The relations between lead level and growth- and obesity-related markers were evaluated using a generalized linear model after adjustment for maternal age, maternal BMI, gestational period, cesarean section, and smoking status. The changes of child weight, height, and BMI z-scores at followed-up months of age after birth by lead exposure were evaluated using a generalized linear model after adjustment for covariates used in the analyses for growth- and obesity-related markers and child's gender. The lead level was positively associated with an increase of birth height ($p = 0.019$) and a decrease of ponderal index at birth ($p = 0.027$) in boys, but not in girls. Moreover, the lead level

Abbreviations: Pb, lead; BMI, body mass index; PI, ponderal index; LOD, limit of detection; SE, standard error.

* Corresponding author at: Department of Environmental Health Sciences, Graduate School of Public Health, Seoul National University, 1 Gwankak-ro, Gwanak-gu, Seoul 08826, Republic of Korea.
E-mail address: ddram2@snu.ac.kr (S. Kim).

http://dx.doi.org/10.1016/j.scitotenv.2017.01.122

Children
Body mass change

was positively associated with increases of BMI z-score after 18 months of age ($p = 0.070$ at 18 months of age; $p = 0.003$ at 24 months of age; and $p = 0.002$ at 27 months of age). Perinatal lead exposure affected accelerated body mass increases at specific times of the children' development.

1. Introduction

Obesity was known to be a major cause of adverse health outcomes including hypertension and diabetes mellitus in adults (DeFronzo et al., 2015; Movahed et al., 2016). In particular, obesity during early life can give rise to permanent metabolic alterations, potentially increasing the chance of obesity later in life (Fowler et al., 2012; Gale et al., 2001; Loos et al., 2001; Loos et al., 2002; Monteiro and Victora, 2005; Tamashiro and Moran, 2010). Recently, childhood obesity has been a growing and alarming problem, associated with changed growth patterns (Monteiro and Victora, 2005; Ong, 2006; Ong et al., 2000). Children with low birth weight were reported to have catch-up growth related with obesity during childhood (Ong et al., 2000; de Zegher et al., 2005). Although several studies have reported an association between prenatal or postnatal exposure and childhood growth, limited studies have been reported for the relation between environmental exposure and childhood obesity (Afeiche et al., 2011; Andrews et al., 1994; Hernandez-Avila et al., 2002; Hong et al., 2014; Shukla et al., 1991).

Lead (Pb) is a ubiquitous environmental contaminant (Boucher et al., 2014). Lead levels have decreased globally mostly due to the conversion to unleaded gasoline in the last few decades in developed and developing countries. However, environmental lead continues to raise public health concerns including fetal and child growth and thus has been studied consistently (Hernandez-Avila et al., 2002). Previous studies have focused on relationships between the prenatal or postnatal exposure to lead and outcomes such as preterm birth, growth including birth weight, and neurodevelopment including cognition, behavior, and school performance (Afeiche et al., 2011; Andrews et al., 1994; Canfield et al., 2003; Chandramouli et al., 2009; Dearth et al., 2002; Hong et al., 2014; Iavicoli et al., 2009; Shukla et al., 1991; Taylor et al., 2014). In particular, blood Pb levels ranging from 5 to 10 μg/dL were well-known to be associated with neurobehavioral disorders and a significant reduction in cognitive capacity in children due to impaired levels of attention, concentration, and memory (Iavicoli et al., 2009). However, previous results were inconsistent with the relation between prenatal lead exposure and childhood growth. Moreover, no longitudinal study was reported on the relation between maternal lead exposure and childhood obesity.

Therefore, in the present study, we measured the levels of lead in cord bloods and evaluated the effect of lead levels in cord blood on childhood body mass index (BMI) during a period of 27 months after birth. We also evaluated the relation between lead level in cord blood and growth- and obesity-related markers determined by birth weight, birth height, head circumference, and ponderal index (PI).

2. Materials and methods

2.1. Study population and sampling

We previously evaluated the association of food consumption during pregnancy with lead levels in cord blood in pregnant women recruited from a study by the Children's Health and Environmental Chemicals in Korea (CHECK) (Kim et al., 2016). The present study was conducted in response to the previous study to estimate the effect of lead in cord blood on body mass change of children after birth. Briefly, a total of 363 healthy pregnant women with mature term singleton were recruited between January 2011 and December 2012 from five hospitals in the Republic of Korea. The eighty three subjects of 363 healthy pregnant women were excluded after delivery, including 28 who had pre-term delivery, medical predisposition, or history of occupational exposure and 55 of which the cord blood sample was unavailable. Finally, 280 mother-child pairs were analyzed in this study. Face-to-face interviews with participants were conducted at enrollment using a structured questionnaire for personal demographics and pregnancy-related information, including maternal age, maternal weight, maternal height, gestational period, cesarean section, income, and smoking status. The weight, height, and head circumference of children at birth were measured by health professionals in each hospital at delivery and PI (100 g/cm^3) and BMI (kg/m^2) were calculated with weight and height at birth; afterwards, their weight and height were measured again by the health professionals at 3, 6, 9, 12, 15, 18, 24, and 27 months of age. To prevent blood coagulation, umbilical cord blood samples were collected at delivery in a K2 EDTA tube (BD Vacutainer K2 EDTA, ref.#368,381, Becton-Dickinson, United Kingdom) directly with a needle using a vacutainer made from polyethylene (BD Vacutainer SST II Advance, ref.#367,953, Becton- Dickinson, United Kingdom). Cord blood collected in the EDTA tube was used for lead measurements. All samples were stored at −80 °C until analysis. The present study was approved by the institutional review board at the School of Public Health, Seoul National University, Republic of Korea (IRB no. 8-2012-04-20), and each study participant provided written informed consent.

2.2. Measurement of lead level in cord blood samples

The level of lead in cord blood was measured according to the method outlined by Butler Walker et al. (2006) with minor modifications (Kim et al., 2016). Briefly, lead level in cord blood was determined using an atomic absorption spectrophotometer (AAS; AA6800, Shimadzu, Japan) with a graphite furnace (GFA-6500, Shimadzu, Japan) at the wavelength of 283.3 nm with a current of 10 mA, using 100 μL of whole blood sample in 1 mL of 1% Triton X-100 solution. In the quality assurance and quality control for lead measurement, the accuracy and recovery range calculated with spiked whole blood were 90%–110% and 85%–100%, respectively. The limit of detection (LOD) for lead was 1.40 μg/L and lead was detected in 273 cord blood samples (detection rate 97.5%).

2.3. Statistical analyses

Basic characteristics and biomarker levels in boys and girls were compared using a *t*-test or a chi-square test. Lead concentrations under LOD were assigned with a proxy value of LOD concentration divided by the square root of two. Lead in cord blood and four growth- and obesity-related markers at birth (weight, height, head circumference, and PI) were log-transformed for normality and the effects of log transformed lead level in cord blood on log transformed growth- and obesity-related markers according to the child's gender were then evaluated using a generalized linear model after adjustment for maternal age, maternal BMI, gestational period, cesarean section, and smoking status. Because the relations between lead exposure and growth- and obesity-related markers differed between boys and girls, associations between lead level in cord blood and z-scores (individual value minus mean value in population/standard deviation in population) of weight, height, and BMI in children at birth, 3, 6, 9, 12, 15, 18, 24, and 27 months were evaluated using a generalized linear model after adjustment of the covariates used in