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Blood cadmium concentrations in Korean adolescents: From the Korea National Health and Nutrition Examination Survey 2010–2013

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ABSTRACT

Objective: To assess blood cadmium levels in Korean adolescents with respect to demographic and lifestyle factors.
Methods: We analyzed data from the Korea National Health and Nutrition Examination Survey from 2010 to 2013, totaling 1472 adolescents aged 10–18 years. Geometric means of blood cadmium were calculated using a complex samples general linear model to compare blood levels in different demographic and lifestyle groups. Multivariate logistic regression analyses were also used to find predictors for high blood cadmium (>90th percentile).
Results: The geometric mean of the blood cadmium concentrations was 0.30 μg/L in Korean adolescents. Older age, type of housing (multifamily house and commercial building), smoking and alcohol consumption, and iron deficiency/iron deficiency anemia (IDA) were significantly associated with higher blood cadmium concentrations ($P < 0.05$). Blood cadmium concentrations were not significantly affected by gender, region, body mass index status, or household income. In multivariate logistic regression analysis, independent predictors for higher blood cadmium levels included current smoker (OR = 7.77), alcohol consumption (OR = 4.31), living in a multifamily house or commercial building (OR = 3.11–3.46), and IDA (OR = 2.64).
Conclusions: Possible associations between blood cadmium levels and type of housing or alcohol consumption in adolescents are suggested for the first time in this study. Further studies are needed to elucidate the mechanism of these findings.

1. Introduction

Cadmium is a naturally occurring heavy metal from the Earth's crust. Main sources of cadmium exposure include foods (*e.g.* plants, seafood) and ambient air that has been polluted by tobacco smoke, house dust, or industrial emissions. Cadmium has a slow elimination rate, and thus accumulates in the human body with age (ATSDR (Agency for Toxic Substances and Disease Registry), 2012). It has a number of negative effects on human health, including nephrotoxicity, carcinogenicity, and neurotoxicity (ATSDR (Agency for Toxic Substances and Disease Registry), 2012; IARC (International Agency for Research on Cancer), 2012).

Children are more susceptible to the toxic effect of heavy metals because they absorb a higher percentage of ingested or inhaled heavy metals than adults (Abelsohn and Sanborn, 2010). Additionally, heavy metals in the blood can be distributed to end organs more easily in children than in adults, possibly owing to immature protective measures, including a blood brain barrier and hepatic detoxification system of xenobiotic metals. As cadmium is an accumulative toxin, it is possible that exposure during childhood could have a negative influence on health later in life (Schoeters et al., 2006). Therefore, national surveillance of blood cadmium levels is essential to identify high-risk population groups and to set strategies for reducing cadmium exposure, particularly in children and adolescents.

Since 2010, data on the blood concentrations of heavy metals have been included in the Korea National Health and Nutrition Examination Survey (KNHANES), spawning numerous studies on national estimates of blood cadmium levels and its negative impact on the adult population (Kim and Lee, 2011; Lee and Kim, 2012a; Park and Lee, 2013). However, only a few studies on the health effect of cadmium exposure in Korean children and adolescents

Abbreviations: KNHANES, Korea National Health and Nutrition Examination Survey; IDA, iron deficiency anemia.

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have been conducted (Choi and Kim, 2005; Lee et al., 2014; Moon et al., 2003).

In the present study, we present the distribution of blood cadmium concentrations according to demographic and lifestyle characteristics and independent predictors for high blood cadmium, using the KNHANES (2010–2013).

2. Material and methods

2.1. Study participants

The present study used data obtained from KNHANES from 2010 to 2013. This is a community-based cross-sectional survey that has been conducted by the Korean Ministry of Health and Welfare to assess health and nutritional status of a large representative sample of noninstitutionalized civilians in Korea. A stratified, multistage probability sampling design is used for selection of household units. Detailed information on the KNHANES design and protocol was provided elsewhere (Kweon et al., 2014) .The cross-sectional analysis was performed in 1472 children and adolescents aged 10–18 years (752 boys, 720 girls) who completed the health examination survey, including the blood cadmium assessment. All participants or their parents provided written consent. This study was exempt from institutional review board approval, as the data used was a publicly available and de-identified dataset.

2.2. Data collection and study variables

The age of the participants was categorized into three groups: 10–12 years, 13–15 years, and 16–18 years. Body mass index (BMI) status was determined according to the sex and age-specific body mass index (BMI) percentile of national reference standards (Moon et al., 2008): underweight (BMI < 5 percentile), normal (BMI ≥ 5 percentile and < 85th percentile), overweight (BMI ≥ 85th percentile and < 95th percentile), and obese (BMI ≥ 95th percentile). Regions were categorized as either rural (administrative divisions of counties or small cities of less than 500,000 population) or urban (administrative divisions of counties or cities of more than 500,000 population). Household income was divided into four quartiles based on equalization of income (household income divided by the square root of the numbers of household members). Type of housing was categorized into five groups: apartment, detached house, row house, multi-family house, and commercial building.

Smoking status was categorized into three groups: non-smoker (participants who have never smoked), secondhand smoke exposure, and current smoker (participants who smoked cigarettes on at least 1 day in the previous 30 days). Alcohol consumption was categorized into three groups. Alcohol consumption was indicated as 'occasionally' when the subjects consumed at least one glass of alcohol every month over the previous year, and indicated as 'excessively' when the subjects consumed 7 drinks or more (for boys) or 5 drinks or more (for girls) on a single occasion more than 2 times per week. If the subjects did not consume every month over the previous year, their alcohol consumption was designated as 'none.'

Iron deficiency was defined as either serum ferritin level of <15 ng/mL or transferrin saturation <16%. Anemia was defined according to World Health Organization (WHO) criteria: Hemoglobin (Hb) <11.5 g/dL from 10 to 11 years, <12.0 g/dL from 12 to 14 years, <13.0 g/dL in boys aged ≥15 years, <12.0 g/dL in girls aged ≥15 years (World Health Organization (WHO), 2001). Iron deficiency anemia (IDA) was defined as having both anemia and iron deficiency.

2.3. Determination of cadmium concentration in whole blood

Overnight fasting blood samples were drawn into standard commercial evacuated tubes containing sodium heparin. Blood cadmium concentrations were measured by graphite furnace atomic absorption spectrometry (AAnalyst 600, PerkinElmer, Finland) with Zeeman-effect background correction. The interassay coefficients of variation were 14.5% at 0.37, 1.11, and 4.30 μg/L. The limit of detection (LOD) for blood cadmium using this method was 0.056 μg/L. The details of blood cadmium analysis have been described in elsewhere (Lee and Kim, 2012b). There were 13 subjects with blood cadmium levels below the LOD. We substituted $LOD/\sqrt{2}$ for levels below the LOD. High blood cadmium was defined as blood cadmium concentration >0.61 μg/gL, which was the 90th percentile in these subjects.

2.4. Statistical analysis

Statistical analysis was performed using SPSS version 18.0 (SPSS, Inc., Chicago, IL, USA). Sampling weights were used in all analyses to take the complex sampling into account. The complex sample descriptive procedure (CSDESCRIPTIVES) was used to evaluate the distribution of demographic and lifestyle variables. For categorical or ordinal variables, the complex-samples crosstabs procedure (CSTABULATE) was used. Blood cadmium levels were log-transformed to calculate the geometric means. Geometric means and 95% confidence interval (CI) were calculated using a complex samples general linear model (CSGLM) to compare blood cadmium levels by different demographic and lifestyle groups after adjusting for all covariates together including age, gender, BMI status, region, type of housing, household income, smoking, alcohol consumption, and body stores of iron. Multivariate logistic regression analyses were also used to determine independent predictors for high blood cadmium (CSLOGISTIC). For all analyses, P values were two-tailed and $P < 0.05$ was considered statistically significant.

3. Results

3.1. General characteristics and blood cadmium concentrations of the study population

General characteristics of the study population are shown in Table 1. Mean age was 14.5 years. No differences between the genders in age, BMI status, region, type of housing, and household income were observed. The proportion of boys who currently smoke ($P = 0.001$) and drink alcohol ($P = 0.004$) were significantly higher in than that of girls. In addition, girls had a higher incidence of IDA and iron deficiency than boys ($P < 0.001$).

Table 2 presents the distribution of blood cadmium concentrations in subjects according to gender and age group. Overall, the geometric mean of blood cadmium levels was 0.3 μg/L (0.33 μg/L in boys, 0.31 μg/L in girls), with the 90th and 95th percentile values at 0.61 μg/L and 0.79 μg/L, respectively.

3.2. Comparisons of blood cadmium concentrations by subjects' characteristics

The crude and adjusted geometric means of blood cadmium concentrations by general demographic and lifestyle factors are listed in Table 3. Blood cadmium levels were not significantly different with regard to gender, residential area, BMI status or household income. The crude and adjusted geometric mean of blood cadmium levels was significantly higher in adolescents aged 13–15 years and 16–18 years than in those aged 10–12 years ($P < 0.001$). Subjects living in a multifamily house or commercial building had