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Blood lead concentration and related factors in Korea from the 2008 National Survey for Environmental Pollutants in the Human Body

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ABSTRACT

This study evaluated blood lead concentrations in the Korean general population and the correlation between various exposure sources using data from the 2008 Korea National Survey for Environmental Pollutants in the Human Body (National Institute of Environmental Research, Korea). The general and occupational characteristics were gathered from 5136 participants who were 20 years of age and older using a structured questionnaire. Blood lead concentrations were analyzed using an atomic absorption spectrophotometer. Statistical analysis was performed using multiple linear regressions of the log lead concentrations to the independent variables such as age, gender, smoke, herbal medication and drug consumption, drinking water, and living area. Geometric mean (GM) blood lead concentrations in Korean adults were 19.7 μg/l. The blood lead concentrations increased with age; the highest concentrations were found in the 50–69-year age group ($p < 0.001$). Males were higher than in females ($p < 0.001$). Current smokers and drinkers had higher concentrations than nonsmokers ($p < 0.001$) and nondrinkers ($p < 0.001$), respectively. People who took herbal medication and drug consumption were higher than those who did not ($p < 0.001$). Education level was negatively associated with blood lead concentration ($p < 0.001$). People living in or around industrial areas had elevated blood lead concentration ($p < 0.001$). Family income was also negatively associated with lead concentration, but not significantly. For drinking water, the underground water (spring or well water) drinking group had higher concentrations than other types of water drinking groups, but not significantly ($p = 0.063$). The blood lead concentrations by occupation were significant ($p < 0.034$): the highest was in laborer and Agricultural–Fishery–Forestry and the lowest in office workers. In women, blood lead concentrations tended to decrease with increasing delivery times, but not significantly. The blood lead concentration (GM) of the general adult population in Korea has decreased over time from 45.8 μg/l (1999) to 19.7 μg/l (2008). Although it is still higher than in other countries such as the United States and Canada, it is rapidly decreasing. Gender, age, smoking and alcohol drinking status, herbal medication and drug consumption, education level, living area and occupation were significantly related to the blood lead concentrations in Korea.

Introduction

The continuous increase in industrial activity has gradually redistributed many toxic metals from the earth's crust to the environment, thereby increasing the possibility of human exposure (Jin et al., 2000). Lead is a naturally occurring element and is especially widespread in our environment. The primary sources of lead

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exposure are paints, water, food, dust soil, and leaded gasoline (McKelvey et al., 2007; Reis et al., 2007).

Over the past century, a lot of reports have described adverse effects caused by lead exposure on the human body such as nervous, renal, endocrine and reproductive systems (Staessen et al., 1996). Also, the blood lead concentration is associated with the prevalence of chronic diseases, such as hypertension and cardiovascular disease. A positive relationship exists between the prevalence of these chronic diseases and blood lead concentration (Schwartz, 1991; Nash et al., 2003; Alghasham et al., 2011). According to a nationwide survey in Korea, blood lead concentration is significantly associated with the risk for metabolic syndrome and cardiovascular disease, and that blood lead concentration had a close relationship with the serum triglyceride level, which is one of the diagnostic components of metabolic syndrome (Rhee et al., 2008).

Human biomonitoring was used to evaluate the exposure status to environmental pollutants in the general population (Son et al., 2009). The United States, Canada, and Germany are among the few countries that have conducted nationally representative human biomonitoring surveys that included testing for heavy metals (Wong and Lye, 2008). In the United States, the 2003–2004 National Health and Nutrition Examination Surveys (NHANES) reported the blood lead concentration [geometric mean (GM) = 15.2 μg/l] for the general population (CDC, 2009). Blood lead concentrations (GM = 17.9 μg/l) have also been reported from a survey of adults in New York State in 2004 (McKelvey et al., 2007). In Canada, the 2007–2008 Canadian Health Measures Survey (CHMS) reported blood lead concentrations (GM = 13.7 μg/l) for the general population (Wong and Lye, 2008). In Germany, the 2003–2006 German Environmental Survey (GerES IV) and Environmental Specimen Bank (ESB) reported blood lead concentrations in children (GM = 16.3 μg/l) (Becker et al., 2008) and adults (below 15.0 μg/l in 2009) (Becker et al., 2013). In Korea, the National Survey for heavy metal concentrations in the blood of the Korean general population was conducted in 2005 (GM of lead = 26.1 μg/l). Subsequently, the Korea National Health and Nutrition Examination Survey (KNHANES) was conducted (2006–2014) by the Centers for Disease Control and Prevention. Around the same time, the Korea National Survey for Environmental Pollutants in the Human Body (KorSEP II, III, 2007–2008) was conducted by the National Institute of Environmental Research and the Ministry of Environment. Subsequently, KorSEP is expended as Korea National Environmental Health Survey (KoNEHS) from 2009 (three-year annual) mainly focused on the exposure status of environmental pollutants in Korean.

In previous study, we have reported information regarding concentrations of heavy metals including lead, as well as the differences in exposure of the population by several known influencing factors (Lee et al., 2012). In this study, subsequently, we attempt to evaluate the correlations among the blood lead concentration and various exposure sources such as socio-demographic and environmental exposure factors to find out the unknown influencing factors and exposure pathways of lead in the general population of Korea on the basis of KorSEP III.

Subjects and methods

Selection of the study population and data collection

The survey population included all non-institutionalized civilian Korean individuals (5136, 20–79 years of age, mean age 57.1). The survey employed stratified multistage probability sampling units based on geographical area, gender, and age, which were determined by household registries of the 2005 National Census Registry (the most recent 5-year national census in Korea at the time). A total of 264,183 primary sampling units, each consisting of approximately 60 households, ultimately constituted the survey sample pool. In the present study, 193 sampling units were randomly selected from the 264,183 primary sampling units in order to represent the overall Korean population: coastal 21 units (10.9%), rural 28 units (14.5%), urban 108 units (56.0%) and industrial 36 units (18.6%). A trained investigator pre-interviewed persons aged ≥19 years of each household on weekend in order to describe the purposes and contents of survey. Randomly, 25 persons per a sampling unit were carried out questionnaire and blood samples were collected in the evening of the weekday. Personal characteristics (e.g., sex, age, delivery, income, and education), occupation, lifestyle factors (e.g., smoking, alcohol drinking, exercise, herbal medication and drug consumption, and type of drinking water) and the environment around the residential area were collected in an interview with pre-training community surveyors using a formatted questionnaire.

Analysis of lead concentration in whole blood

Blood specimens were collected (from April to September, 2008) in the local health centers located in each sampling units by medical personnel followed by questionnaire using the K2 EDTA Plus Blood Collection Tubes (BD Vacutainer, Becton, Dikinson, and Company, Franklin Lakes, NJ, USA), mixed for 20 min and stored at −24 °C until analysis. The lead concentration in whole blood was measured using a graphite furnace atomic absorption spectrophotometer (Analyst 800; PerkinElmer, Waltham, MA, USA). We used an atomic absorption spectrophotometer equipped with Zeeman-effect-based background corrector, AS-800 autosampler, and a lead hollow cathode lamp, as well as pyrolytic graphite-coated tubes with platforms. Calibration was performed using dilutions of an aqueous lead reference solution (1000 ppm; Sigma, St. Louis, MO, USA). Standards solutions (5, 10, 20, 40, 80, and 120 μg/l) were prepared by dilution with distilled water. Standards solution and whole blood samples were also diluted (1:10) with an aqueous matrix modifier solution [containing 0.2% Triton X-100 and 0.2% $(NH_4)_2HPO_4$]. The limit of detection for this method was 4.8 μg/l. Detectable blood lead concentrations were determined from 99.7% of the subjects. Analysis of lead concentrations in whole blood carried out in the Institute of Environmental and Occupational Medicine, Inje University, an agency for lead analysis of KorSEP III (2008).

Quality control

Analytical techniques were performed using quality control programs (internal and external) with satisfactory results. Internal quality control samples were analyzed at the beginning, middle, and endpoints of each batch (80 samples in each batch) of blood specimens and throughout each analytical run. The precision and accuracy of the analytical methods were 5.65% and 98.9%, respectively. External quality control was evaluated by participating in the 2008 (G-EQUAS, 41st, 42nd) German Quality Assessment Scheme (Institute for Occupational, Social and Environmental Medicine, University of Erlangen-Nuremberg, Germany on behalf of the German Society of Occupational and Environmental Medicine). The analytical results were within the tolerance ranges (within 8.5% compared with reference values) supplied by the manager of the German External Quality Assessment Scheme. The coefficients of variation of analytical samples were within 10.0%.

Statistical analysis

To examine the factors influencing blood lead concentration in the Korean general population, the following independent