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Relationship of lead and essential elements in whole blood from school-age children in Nanning, China

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ABSTRACT

Objectives: The aim of this study was to investigate blood lead level and its relationship to essential elements (zinc, copper, iron, calcium and magnesium) in school-age children from Nanning, China.
Methods: A total of 2457 children aged from 6 to 14 years were enrolled in Nanning, China. The levels of lead (Pb), zinc (Zn), copper (Cu), iron (Fe), calcium (Ca) and magnesium (Mg) were determined by an atomic absorption spectrometer.
Results: The mean blood lead level (BLL) was 57.21 ± 35.00 μg/L. 188 (7.65%) asymptomatic children had toxic lead level higher than 100 μg/L. The school-age boys had similar lead level among different age groups, while the elder girls had less BLL. The blood Zn and Fe were found to be increased in the boys with elevated BLL, but similar trends were not observed in the girls. Positive correlations between Pb and Fe or Mg ($r = 0.112$, 0.062, respectively, $p < 0.01$) and a negative correlation between Pb and Ca ($r = -0.047$, $p < 0.05$) were further established in the studied children.
Conclusions: Lead exposure in school-age children was still prevalent in Nanning. The boys and girls differed in blood levels of lead and other metallic elements. Lead exposure may induce metabolic disorder of other metallic elements in body.

1. Introduction

Although lead (Pb) is a highly toxic metal, it is commonly used in industries of construction, automobile battery and even as gasoline additives worldwide [1]. Environmental lead exposure, affecting both adults and children, is increasingly becoming a healthy concern [2,3]. Pb enters into the body mainly through the respiratory system and the digestive tract, and causes a series of documented adverse effects particularly in the nervous systems [4–6], such as developmental delays, insomnia, irritability, tremors, hearing loss, deficits in behavioral functioning, impaired cognitive and learning abilities, and social withdrawal [7–9]. Since children have underdeveloped and inadequate blood brain barrier, unrestricted Pb accumulation in the brain will eventually disrupt neural signal transduction and irreversibly damage the nervous system [10–13]. Thus, it is important to prevent or limit lead exposure especially in children.

Nutritional essential elements such as iron (Fe), zinc (Zn), calcium (Ca), copper (Cu), and magnesium (Mg) are coactivators of several important enzymes and proteins which are necessary for health maintenance [14,15]. However, lead exposure, even at low concentration, can cause metabolic disorder of other metallic elements in the body [8,16,17]. Some studies found that elevated BLL will decrease the plasma concentration of Fe, Ca and other nutritional metallic elements [18]. Moreover, low absorption of these elements can further enhance the intake and toxicity of Pb [19]. Therefore, there are possible feedback loops between blood lead and these essential metals.

Many studies in China have established the relationships between lead and other metallic elements mainly in preschool children aged 0–6 years. However, fewer analyzed school-age children. In the present study, we investigated the concentrations of Pb, Zn, Cu, Fe, Ca and Mg in the blood of school-age children aged 6–14 years from Nanning, China. This study was aimed to evaluate the extent of the toxic exposure of Pb among school-age children and study the relationship between Pb and other essential elements.

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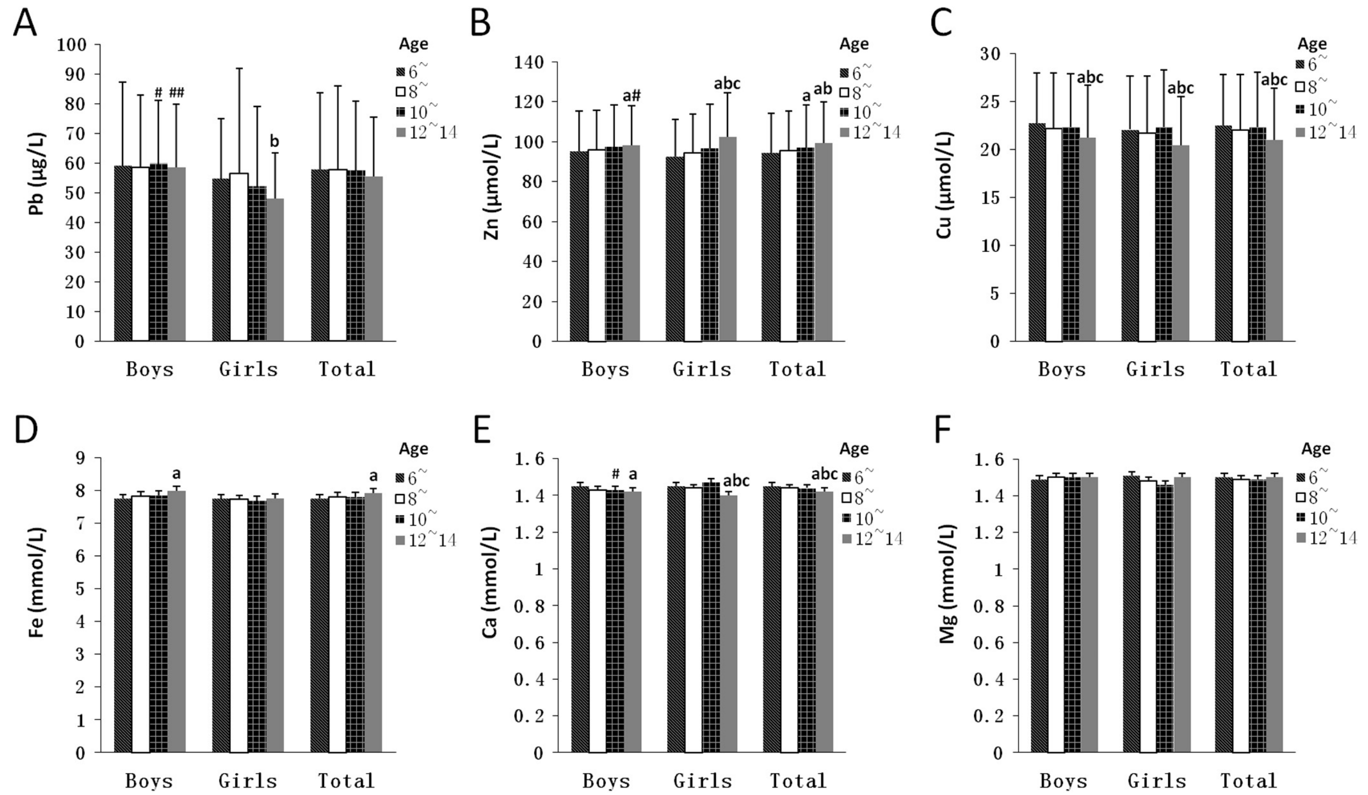

Fig. 1. Comparison of blood metallic elements among different age groups of boys and girls.
The children were divided into 4 different age groups (6∼, 8∼, 10∼ and 12 ∼ 14) as indicated. The concentration of Pb (A), Zn (B), Cu (C), Fe (D), Ca (E) and Mg (F) were determined by atomic absorption spectrometers. Statistical comparisons were conducted using ANOVA and Student's *t*-test.
$^{a}P < 0.05$, compared with 6∼ group; $^{b}P < 0.05$, compared with 8∼ group; $^{c}P < 0.05$, compared with 10∼ group; $^{\#}P < 0.05$, compared with girls; $^{\#\#}P < 0.01$, compared with girls.

2. Material and methods

2.1. Study population

The study protocol was reviewed and approved by Institutional Review Boards of Guangxi Medical University in Nanning, China. Guardians of the recruited children signed the informed consents. A total of 2457 urban children (1719 boys and 738 girls) in Nanning, China had a routine health screening and were then recruited in the present study. It was important to note that the children studied have not yet developed any observable symptoms of lead toxicity. Those who have suffered or were suffering congenital or contagious diseases were excluded. Subjects were divided into four groups according to their ages: 6∼ group (aged from 6 to 7), $N = 450$; 8∼ group (8 to 9), $N = 529$; 10∼ group (10 to 11), $N = 377$; 12∼14 group (12 to 14), $N = 363$.

2.2. Blood collection and preparation

Peripheral venous blood (2 ml) were collected into lead-free vacuum tubes containing heparin sodium and stored at −20 °C until further analysis, as described previously [14]. 0.2 ml of the blood was diluted with 0.45% TritionX-100 and then supplemented with 0.1% nitric acid and palladium chloride (Sinopharm Chemical reagent Co., Ltd., Shanghai, China).

2.3. Measurement of metallic elements

Pb level was detected by a graphite furnace atomic absorption spectrometer (GFAAS) (Shimadzu AA-6300, Japan). The concentrations of Zn, Cu, Fe, Ca and Mg were analyzed by a flame atomic absorption spectrometer (FAAS) (Shimadzu AA-6800, Japan). The standards of these elements above were purchased from National Research Center for Certified Reference Materials, China. The measurement of blood samples was performed as described previously [20]. Each sample was detected in duplicate.

To ensure data validity, certified reference material for Pb in freeze-dried cow blood (GBW09139∼GBW09140, Chinese Center for Disease Control and prevention) was used through the whole procedure. The detection accuracy of all measurements was more than 90% using the certified reference material. The limits of detection (LOD) of Pb, Zn, Cu, Fe, Ca and Mg were1.2, 2.1, 0.3, 17.5, 20.4 and 3.5 ng/ml, respectively.

Precaution measures were taken to avoid contamination. Trace element-free material was used for sampling and storage to reduce the risk of contamination. Tubes and glassware were soaked in 20% nitric acid for 24 h and rinsed eighteen to twenty times with deionized water provided by pharmaceuticals industry of Guangxi Medical University.

2.4. Statistical analysis

Statistical analyses were conducted with SPSS 16.0 (SPSS, Chicago, USA). The blood levels of each metallic element among different age-groups or gender-groups were compared using one-way analysis of variance (ANOVA) or Student's *t*-test. The proportion of children with toxic Pb level was compared by chi-square test. Pearson's correlation analysis was conducted to assess correlations between BLL and other five elements. A two-tailed *P* value <0.05 was used to indicate statistical significance.