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The blood lead levels of outpatients aged 1–18 years from Lu'an, China, 2012–2014

Meichun Zhang*,[1], Shengfang Guang[1], Rongrong Zhai, Jie Liu, Hui Guang, Dong Chen, Benzhong Li, Songtao Zhang

Clinical Laboratory Center, Lu'an People's Hospital, The Lu'an Affiliated Hospital of Anhui Medical University, Lu'an 237005, People's Republic of China

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ABSTRACT

To evaluate blood lead levels (BLLs) and possible influencing factors among children and adolescents in Lu'an, we collected blood samples of 3266 outpatients aged 1–18 years from January 2012 to December 2014 and BLLs were determined by atomizer absorption spectrophotometer. The results showed that the geometric mean (GM) of BLLs was 29.53 μg/L (95% CI: 29.00–30.06 μg/L) and the prevalence of BLLs ≥50 and 100 μg/L were 17.7% and 0.2%, respectively. The GM BLLs and prevalence of BLLs ≥50 μg/L were increased with age before 7 years old and then slightly decreased, and, contrary to previous studies, they were the highest at Jan–Feb and the lowest at Sep–Oct. From 2012 to 2014, the GM BLLs were significantly increased ($P < 0.001$) while the prevalence of BLLs ≥50 μg/L was decreased but with no significant difference ($P > 0.05$). These results suggested that although the BLLs of Lu'an children were lower than most areas of China and several neighboring cities as previously reported, they were still higher than that of developed countries. Meanwhile, the GM BLLs of children and adolescents from Lu'an have a trend of increase in recent years. A lot of future works need to be done to identify the risk factors for lead exposure.

1. Introduction

The adverse health effects of lead exposure, especially in children, have emerged as a global public health problem. As a kind of multi-system toxin, lead exposure can affect nearly every system in the body [1–4]. The common activities of a child such as playing on the floor or ground, chewing toys, sucking on fingers, and dietary habits such as eating canned foods and drinking beverages, all make children more susceptible to lead exposure than adults [3,5].

In 1991, the US CDC defined an elevated blood lead level (BLL) as those ≥100 μg/L for children [6]. However, subsequent studies showed that BLLs less than 100 μg/L and even 50 μg/L could also have adverse effects on children's health [7–10]. Therefore, there is no safe threshold of BLL in children.

Lu'an (116°30′37″E, 31°44′40″N) is a "Nationally Designated Garden City" located in eastern China. The heavy industry of the city is relatively undeveloped and environmental pollution is low. However, as a member of "Industrial Shift Demonstration Area of the City Cluster along Anhui–Yangtse River", a national development program launched in 2010, the economic development including industry is a focus of Lu'an in recent years. This would bring the risk of lead pollution and elevated BLLs in children. Moreover, the BLLs were mostly reported in children younger than 6 years old in China [11]. The studies for school-age children and adolescents are still scarce.

Thus, in the present study, the BLLs of Lu'an children and adolescents aged 1–18 years were detected from 2012 to 2014, after the above national program launched. These data will provide the information about the current status of BLLs, and work as a reference for future assessment of BLLs in children and lead pollution that accompany the economic development proposed by the above national program.

2. Materials and methods

2.1. Study population and sample collection

The population that we studied consisted of 3266 relatively healthy children and adolescents (2191 boys and 1075 girls aged

Abbreviations: BLL, blood lead level; GM, geometric mean; CI, confidence interval; OR, odds ratios.

* Corresponding author. Fax: +86 564 3338112.
E-mail address: z02m14c588@aliyun.com (M. Zhang).

[1] These authors contributed equally to this work.

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1–18 years) from the outpatient department of the Lu'an Affiliated Hospital of Anhui Medical University. They all came for the routine health examination between January 2012 and December 2014. Inclusion criteria were as follows: no thyroid diseases, kidney diseases, nutritional deficiency diseases, congenital or contagious diseases, or other diseases that could affect the blood levels of the measured elements, and living in Lu'an city of Anhui province. Those who take any mineral supplements or vitamins were excluded from the study. Informed consent for the use of these children's detection results and personal information in this study was obtained from their parents or guardians. This study was approved by the Ethics committee of Lu'an People's Hospital (process number: LAYY-2011-05). For all of the outpatients, about 2 ml of whole blood sample was drawn into a vacuum blood collection tube with sodium heparin anticoagulant (CHGD®, Gaode, Wenzhou, China). Prior the blood lead assay, all the samples were kept at 4 °C for no more than 48 h.

2.2. Elemental analysis

For blood lead determination, 40 μl of the whole blood was mixed with 360 μl diluents (ammonium phosphate, Triton X-100, bovine serum) for lead detection and then analyzed by an atomic absorption spectrometry (283.3 nm) equipped with a tungsten atomizer (BH2100, Bohui, Beijing, China). Calcium, iron, copper, magnesium and zinc were analyzed by flame atomic absorption spectrometry (BH5100, Bohui, Beijing, China) with hollow cathode lamps under 422.7, 248.3, 324.7, 285.2, and 213.9 nm, respectively. Quality controls were assured by analyzing certified reference materials GBW(E) 090033, 090034, 090035, and 090036 for lead and GBW(E) 080915, 080916, and 080917 for other five essential elements from General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China. Reference samples were analyzed every ten routine sample detection. If the values exceeded the uncertainty provide by the certificate of reference materials, the previous ten routine samples must be analyzed again. The sample analysis was carried out according to the instructions for the instrument. For lead analysis, the detection and quantification limits were 2.63 and 8.76 μg/L, respectively, and within- and between-run coefficients of variation were 5.76–10.55% and 7.49–11.28%, respectively.

2.3. Data analysis

Statistical analysis was performed using SPSS version 19. Geometric means (GM) with 95% confidence interval (CI) and medians with IQR (interquartile range) of BLLs were calculated. Because of the non-normal distribution, the values of BLLs were $\log_{10}$-transformed. The differences of GM BLLs between sexes, and among age-, month- and year-groups were analyzed by Student's *t*-test and one-way ANOVA, respectively. Chi-square analysis was used to compare the differences of prevalence of BLLs ≥50 μg/L between different sub-groups. The data of BLLs ≥100 μg/L was not analyzed because there were only 0.2% (6/3266) outpatients with the high value. The associations of high BLLs with sex, age, month and year of samples collection were also analyzed by using multivariable logistic and linear regression. The correlation of BLLs with other elements was analyzed by Spearman's correlation coefficient. A *p*-value <0.05 (two-tailed) was considered as statistically significant.

3. Results

3.1. BLLs in children and adolescents of Lu'an

The outpatients in the study consisted of 2191 boys (67.1%) and 1075 girls (32.9%), and aged 1–18 years with a mean age of 6.45 ± 4.32 years. The GM BLLs and the differences of them between sexes and among age-, month- and year-groups were shown in Table 1. The overall GM BLL was 29.53 μg/L (95% CI: 29.00–30.06) with a median of 30 μg/L and IQR of 21–43 μg/L.

The GM BLLs were increased with age before 7 years old, especially from 3 to 5 years old with the highest value of 31.4 μg/L at 5–6 years old, and then decreased slightly and maintained at about 30 μg/L from 7 to 18 years old. The difference of GM BLLs among different months was significant ($P < 0.001$) (Table 1). The GM BLLs decreased gradually from January to October and then increased slightly, with the highest of 34.43 μg/L at January–February and the lowest of 26.57 μg/L at September–October. The GM BLL of January–February was significantly higher than that of all other months. In the study, we found that the GM BLLs from 2012 to 2013 were almost the same and about 28 μg/L, but significantly increased to 31.31 μg/L at 2014 ($P < 0.001$). There was no significant difference of GM BLLs between sexes (Table 1).

In multivariate linear regression, all risk factors associated with higher GM BLLs in Table 1 were still statistically significant after adjusted for sex, age, month and year of samples collection (Table 2).

3.2. Prevalence of BLLs ≥50 μg/L

Since there were only 0.2% (6/3266) of the outpatients with BLLs ≥100 μg/L, the reference level of 50 ug/L was used as high BLL in the study. The results are shown in Fig. 1.

The overall prevalence of BLLs ≥50 μg/L was 17.7% and it was only slightly higher in boys than in girls with no significant difference was observed ($P > 0.05$). From age 1 to 6 years, the prevalence of BLLs ≥50 μg/L increased rapidly with the highest of 21.2% at age 5–6 years and then slowly decreased. The lowest prevalence was 14.2% at age 1–2 years. In total, from January to October, the prevalence of BLLs ≥50 μg/L decreased rapidly, except for May–June with the prevalence of 22.2% and second in prevalence to 28.3% in January–February, with a slight increase observed in November–December. The prevalence of BLLs ≥50 μg/L from 2012 to 2014 decreased gradually, but without statistically different ($P > 0.05$). These risk factors associated with BLLs ≥50 μg/L were still statistically significant in multivariate logistic regression after adjusted for sex, age, month and year of samples collection (Table 2).

3.3. Distribution of BLLs

The distribution of BLLs across 4 categories including <25, 25–49, 50–74 and ≥75 μg/L was analyzed and presented in Fig. 2. In total, the results showed that the distributions of BLLs from high to low were as follows: 47.6% were 25–49 μg/L, 34.7% were <25 μg/L, 15.5% were 50–74 μg/L, and 2.2% were ≥75 μg/L. The trends of distribution of BLLs among different sub-groups (sexes, ages, months and years) were similar.

3.4. Comparisons of BLLs between Lu'an and neighboring cities

The BLLs of Lu'an children and adolescents were compared with two neighboring cities: Hefei and Anqing, and the average value of whole Anhui province. The results were shown in Table 3. For the data of BLLs from different cities comparable, we conducted the comparisons between the BLLs in 2012 of Lu'an and those BLLs of neighboring cities that detected not earlier than 2009 and at the similar age stages.

At the corresponding age stages, both the mean and GM BLLs of Lu'an children were significantly lower than that of Hefei, Anqing and the average values of Anhui province (Table 3). The prevalence of BLLs ≥ 50 μg/L of Lu'an children at age 1–6 and 1–14 years in