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Surveillance of Childhood Blood Lead Levels in 14 Cities of China in 2004-2006

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Objective To investigate the blood lead level in children aged 0-6 years in urban areas of China. **Methods** Fourteen cities were selected as sites under surveillance. A total of 44 045 peripheral blood specimens were collected from 2004 to 2006, during which 15 727, 14 737, and 13 584 specimens were tested in 2004, 2005, and 2006, respectively. Tungsten atomizer absorption spectrophotometer was employed to determine blood lead level. **Results** The geometric mean blood lead level in the tested children was 47.10 μg/L with 10.10% ⩾100 μg/L, 46.17 μg/L with 7.78% ⩾100 μg/L, and 47.03 μg/L with 7.30% ⩾ 100 μg/L in 2004, 2005, and 2006, respectively. The blood lead levels seemed to tend to rise in parallel with the increase of age of the children and were higher in boys (48.84 μg/L, 47.56 μg/L, and 47.78 μg/L in the 3 respective years) than in girls (45.00 μg/L, 44.53 μg/L, and 46.13 μg/L). **Conclusion** The blood lead levels in children in cities of China are lower than those in previous national studies, but higher than those in developed countries. Childhood lead poisoning remains a public health problem in China.

Key words: Lead; Lead exposure; Epidemiology; Children; China

INTRODUCTION

The persistence of lead in the environment poses an ongoing challenge to public health. Lead is an environmental toxicant which may decrease intelligence, growth and hearing, and cause anemia, attention deficits and behavioral problems in children[1]. Meanwhile, lead poisoning is preventable. Strategies to eliminate lead poisoning include reducing exposure sources, developing safe and effective abatement programs, and identifying persons at risk[2]. Surveillance plays an important role in documenting lead exposure by identifying vulnerable population groups and assessing the effectiveness of intervention efforts.

In recent years, lead poisoning has been received serious attention from Chinese scientists, and many researches have documented a high prevalence of lead poisoning in children and have aroused widespread public concern via media. One paper reported in 2004 that the average blood lead level is 98.33 μg/L and 30.21% of 2 682 tested kids in kindergartens of Shenyang city have a blood lead level ⩾ 100 μg/L[3]. It was reported in 2000 that 77.5% of 394 children aged 0-6 years in Taiyuan city have a blood lead level ⩾100 μg/L[4]. In contrast, blood lead levels in some studies are not so high. It was reported in 2002 that the average blood lead level in 521 preschool children of Changsha city is 47.5 μg/L and 9.6% of these children have a blood lead level ⩾ 100 μg/L[5]. However, most studies performed to date focused merely on subjects living in highly polluted areas. In addition, the sample sizes were generally small. Thus, there is little information available about the blood lead levels in children of China.

To investigate the degree of lead exposure in children aged 0-6 years in cities, we conducted a specific surveillance of blood lead levels in 14 cities with a large metropolitan area and advanced industry and economy.

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MATERIALS AND METHODS

Sites of Survey

Fourteen cities in different parts of China were selected as the sites under surveillance (Table 1).

Subjects

Children aged 0-6 years were sampled from each city. Children aged 3-6 years were sampled from kindergartens during the regular check-up while those aged 0-2 years were sampled in community child health clinics during their mandatory and periodic visits. Children and their parents were enrolled in the order of their arrival at each kindergarten on recruitment days.

As the analysis of blood lead is free, most of parents agreed to enroll their children in the study. After parents gave their informed consent for their children's participation in the study, capillary blood sample was collected from each child at the enrollment site in accordance with guidelines developed by the Centers for Disease Control and Prevention (US CDC)[6]. Before sample collection, each child's hand was washed thoroughly with soap and water, and the pad of the finger to be punctured was cleaned with an alcohol swab. Capillary sampling is virtually unbiased (average error: +10 μg/L) when hands are cleaned properly before blood is drawn as described elsewhere[7]. A whole blood specimen of 40 μL was obtained from each participant. A total of 44 045 blood specimens were obtained from 2004 to 2006. The distribution of the samples is described in Table 1.

TABLE 1

Distribution of the Surveillance Spots and Samples

Location	City	2004	2005	2006	Total
North	Beijing	1116	1208	960	3284
	Shijiazhuang	1169	1296	1212	3677
	Huhhot	1190	746	1028	2964
Northeast	Harbin	1276	1255	542	3073
	Dalian	1222	1503	543	3268
East	Hefei	1007	941	1005	2953
	Qingdao	1164	834	1537	3535
South	Guangzhou	1230	845	945	3020
	Haikou	850	940	492	2282
Southwest	Chengdu	1347	727	901	2975
Northwest	Xi'an	850	657	1167	2674
	Yinchuan	1155	1414	1165	3734
Middle	Wuhan	1232	1281	1163	3676
	Zhengzhou	919	1090	921	2930
All		15 727	14 737	13 581	44 045

Laboratory Test

Blood specimens obtained from the participants were put into a centrifuge tube containing a special diluent, mixed well, stored at 4 ℃ and then shipped to the local maternal and children health centre for analysis. All the specimens were analyzed within a week after collection. Lead was measured with a BH2100 Tungsten atomizer absorption spectrophotometer (Beijing Bohui Innovation Technology Co., Ltd.). Analysis of each specimen was performed in duplicate, and the mean of the duplicate measurements was recorded.

Blood lead reference materials, GBW09139 and GBW09140, used to ensure quality control, were obtained from the Chinese Center for Disease Control and Prevention.

Quality control materials were measured at the beginning and end of each day of laboratory analyses to ensure that all equipments were properly calibrated. One quality control material had to be measured after every 20 study specimens were analyzed and all the results were between the allowance limits.

TABLE 2

Geometric Mean (GM) of Blood Lead Levels and Percentage of Blood Lead Level ≥100 μg/L in Children Aged 0- 6 Years in Cities of China, during 2004-2006

	2004			2005			2006			Total		
	n	GM (CI§-GM)	%≥100 μg/L (CI-%)	*n*	GM (CI-GM)	%≥100 μg/L (CI-%)	*n*	GM (CI-GM)	%≥100 μg/L (CI-%)	*n*	GM (CI-GM)	%≥100 μg/L (CI-%)
All	15727	47.10 (46.62-47.58)	10.10 (9.64-10.59)	14737	46.17 (45.69-46.65)	7.78 (7.35-8.22)	13581	47.03 (46.54-47.52)	7.30 (6.87-7.75)	44045	46.76 (46.48-47.04)	8.46 (8.20-8.72)
Age*												
0	1081	37.43 (35.96-38.95)	5.64 (4.34-7.19)	1017	39.86 (38.30-41.48)	4.72 (3.50-6.21)	1217	36.16 (34.68-37.69)	5.01 (3.86-6.39)	3315	37.67 (36.80-38.57)	5.13 (4.40-5.93)
1	1356	43.34 (41.87-44.85)	7.89 (6.51-9.46)	906	38.37 (36.80-40.00)	4.75 (3.46-6.34)	1300	40.10 (38.67-41.58)	5.85 (4.63-7.26)	3562	40.84 (39.97-41.73)	6.34 (5.57-7.20)
2	1503	46.43 (44.99-47.91)	8.65 (7.27-10.19)	1158	41.69 (40.14-43.27)	6.39 (5.05-7.96)	973	44.98 (43.26-46.77)	6.89 (5.38-8.66)	3634	44.48 (43.58-45.40)	7.46 (6.62-8.36)
3	3244	47.19 (46.13-48.27)	10.27 (9.24-11.36)	2997	46.50 (45.42-47.59)	7.91 (6.97-8.93)	2094	47.41 (46.23-48.62)	6.68 (5.65-7.84)	8335	46.99 (46.35-47.64)	8.52 (7.93-9.14)
4	3473	48.35 (47.32-49.41)	10.86 (9.84-11.93)	3959	49.25 (48.29-50.22)	9.14 (8.26-10.08)	3316	50.62 (49.65-51.62)	7.63 (6.75-8.59)	10748	49.37 (48.80-49.95)	9.22 (8.68-9.78)
5	3208	48.83 (47.73-49.96)	11.25 (10.18-12.40)	3172	47.90 (46.84-48.98)	8.51 (7.56-9.54)	3079	49.95 (48.94-50.98)	7.41 (6.50-8.39)	9459	48.88 (48.26-49.50)	9.08 (8.51-9.78)
6	1862	51.59 (50.12-53.11)	11.82 (10.38-13.37)	1528	47.43 (46.02-48.87)	7.32 (6.07-8.75)	1602	50.77 (49.28-52.31)	10.42 (8.97-12.03)	4992	50.02 (49.17-50.89)	10.00 (9.18-10.86)
Sex*												
Male	8716	48.84 (48.18-49.52)	11.13 (10.47-11.81)	8065	47.56 (46.90-48.23)	8.68 (8.07-9.32)	7352	47.78 (47.10-48.47)	8.26 (7.64-8.91)	24134	48.09 (47.70-48.48)	9.43 (9.06-9.81)
Female	7011	45.00 (44.31-45.69)	8.83 (8.17-9.52)	6672	44.53 (43.85-45.22)	6.68 (6.10-7.31)	6229	46.13 (45.44-46.83)	6.18 (5.60-6.81)	19911	45.19 (44.79-45.59)	7.28 (6.93-7.65)
City												

(to be continued)

(continued)

	2004			2005			2006			Total		
	n	GM (CI§-GM)	%≥100 μg/L (CI-%)	*n*	GM (CI-GM)	%≥100 μg/L (CI-%)	*n*	GM (CI-GM)	%≥100 μg/L (CI-%)	*n*	GM (CI-GM)	%≥100 μg/L (CI-%)
Hefei	1007	47.57 (45.77-49.44)	8.94 (7.25-10.87)	941	60.28 (58.44-62.18)	8.29 (6.61-10.24)	1005	67.46 (65.00-70.00)	23.58 (20.99-26.33)	2953	57.77 (56.55-59.02)	13.65 (12.43-14.94)
Zhengzhou	919	60.58 (58.68-62.54)	13.38 (11.25-15.76)	1090	49.56 (47.88-51.29)	8.44 (6.86-10.25)	921	63.35 (61.57-65.18)	10.86 (8.92-13.05)	2930	57.01 (55.94-58.10)	10.51 (9.42-11.68)
Haikou	850	59.47 (57.25-61.77)	17.88 (15.36-20.63)	940	53.10 (51.31-54.96)	9.68 (7.87-11.75)	492	58.99 (56.87-61.20)	6.10 (4.15-8.59)	2282	56.66 (55.45-57.90)	11.92 (10.62-13.32)
Wuhan	1232	56.73 (55.04-58.47)	9.74 (8.14-11.53)	1281	53.49 (51.69-55.36)	7.10 (5.76-8.65)	1163	59.45 (57.78-61.17)	9.37 (7.76-11.19)	3676	56.41 (55.40-57.44)	8.62 (7.74-9.58)
Chengdu	1347	59.35 (57.76-60.98)	14.18 (12.36-16.16)	727	48.46 (46.59-50.40)	4.54 (3.14-6.32)	901	56.23 (54.27-58.26)	8.32 (6.60-10.32)	2975	55.56 (54.51-56.63)	9.95 (8.90-11.08)
Guangzhou	1230	51.91 (50.29-53.59)	9.92 (8.30-11.73)	845	65.01 (62.57-67.54)	15.50 (13.13-18.12)	945	44.15 (42.19-46.20)	8.25 (6.58-10.19)	3020	52.55 (51.38-53.75)	10.86 (9.77-12.03)
Shijiazhuang	1169	45.59 (43.86-47.39)	10.01 (8.35-11.87)	1296	46.76 (44.83-48.78)	17.59 (15.56-19.78)	1212	49.12 (47.56-50.74)	2.72 (1.88-3.80)	3677	47.15 (46.12-48.20)	10.28 (9.32-11.31)
Xi'an	850	52.99 (50.71-55.38)	14.71 (12.39-17.27)	657	45.48 (43.65-47.40)	5.48 (3.87-7.51)	1167	41.07 (39.41-42.81)	8.48 (6.95-10.23)	2674	45.67 (44.53-46.84)	9.69 (8.59-10.87)
Beijing	1116	43.67 (42.01-45.40)	9.14 (7.51-10.98)	1208	47.06 (45.30-48.89)	7.86 (6.41-9.53)	960	44.22 (42.73-45.77)	6.77 (5.26-8.55)	3284	45.05 (44.09-46.04)	7.95 (7.05-8.93)
Harbin	1276	47.33 (45.84-48.87)	9.56 (8.00-11.31)	1255	39.85 (38.54-41.20)	3.82 (2.83-5.04)	542	47.70 (46.02-49.44)	3.87 (2.41-5.86)	3073	44.18 (43.29-45.08)	6.22 (5.39-7.13)
Yinchuan	1155	41.35 (39.35-43.45)	14.98 (12.97-17.17)	1414	46.19 (44.57-47.86)	10.33 (8.79-12.03)	1165	41.18 (39.57-42.85)	8.15 (6.65-9.88)	3734	43.06 (42.04-44.10)	10.98 (9.99-12.03)
Qingdao	1164	38.90 (37.52-40.33)	6.62 (5.26-8.20)	834	32.04 (30.95-33.16)	0.48 (0.13-1.22)	1537	37.51 (36.56-38.48)	0.85 (0.45-1.44)	3535	36.57 (35.91-37.25)	2.63 (2.13-3.21)
Huhhot	1190	32.64 (31.36-33.97)	2.69 (1.85-3.78)	746	45.33 (43.64-47.08)	4.96 (3.52-6.77)	1028	33.98 (32.69-35.32)	3.70 (2.63-5.04)	2964	35.95 (35.12-36.80)	3.51 (2.88-4.24)
Dalian	1222	37.63 (36.29-39.01)	3.52 (2.56-4.71)	1503	33.08 (32.01-34.20)	3.86 (2.94-4.96)	543	37.02 (35.18-38.95)	0.92 (0.30-2.14)	3268	35.37 (34.60-36.16)	3.24 (2.66-3.91)

Note. § 95% confidence interval. *The difference was significant at $P<0.05$ for geometric means and for the percentage of children with blood lead level ≥ 100 μg/L among age groups and between male and female.

Statistical Analysis

Statistical analyses were conducted with Stata8.0. Geometric mean blood lead level, percentile values, and percentage of children with their blood lead level ⩾ 100 μg/L were calculated, for 10 μg lead/dL blood (100 μg/L) has been defined as the level of concern for lead exposure the US CDC[8]. Differences between results by age and sex were evaluated in a pairwise fashion for statistical significance at alpha=0.05, with *t* tests.

RESULTS

The geometric mean of blood lead levels in the 44 045 children aged 0-6 years under surveillance was 46.76 μg/L (95% confidence interval: 46.48-47.04 μg/L) (Table 2). The blood lead level ranged 10-790 μg/L. More than two fifths (42.58%) of the children had a blood lead level between 50 μg/L and 100 μg/L. The proportions of children with a blood lead levels at or above 50, 100, 150, 200, 250, and 450 μg/L were 51.04%, 8.46%, 1.79%, 0.73%, 0.49%, and 0.20%, respectively.

The difference in geometric mean and percentage of children with a blood lead level ⩾100 μg/L between boys and girls was significant ($P<0.05$). The geometric mean of blood lead levels was 47.10 μg/L, 46.17 μg/L and 47.03 μg/L in 2004, 2005, and 2006, respectively, with no significant difference. The prevalence of elevated blood lead level ⩾ 100 μg/L was 10.10%, 7.78%, and 7.30% in 2004, 2005, and 2006, respectively ($P<0.05$). The prevalence of blood lead level ⩾ 200 μg/L in childre was less than 1%, 0.57%, 0.82%, and 0.77% in 2004, 2005, and 2006, respectively.

The geometric mean of blood lead levels and the prevalence of elevated blood lead levels were significantly higher in boys than in girls (Figs. 1-2).

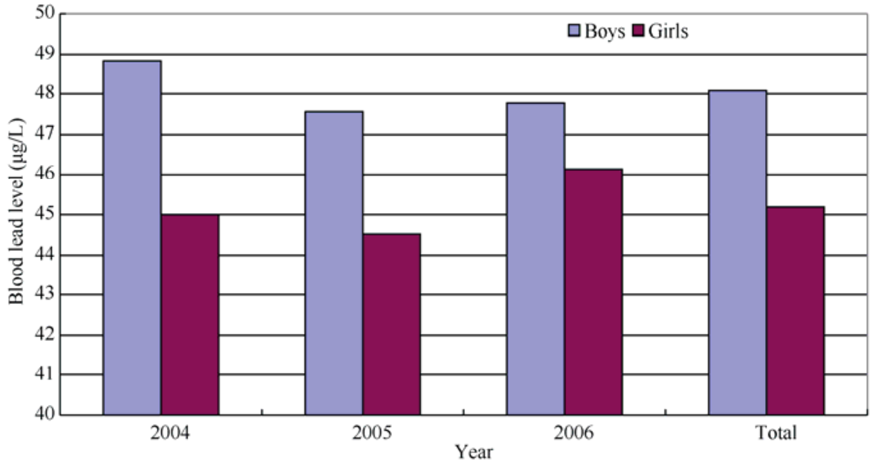

FIG. 1. Geometric mean of blood lead levels by gender.

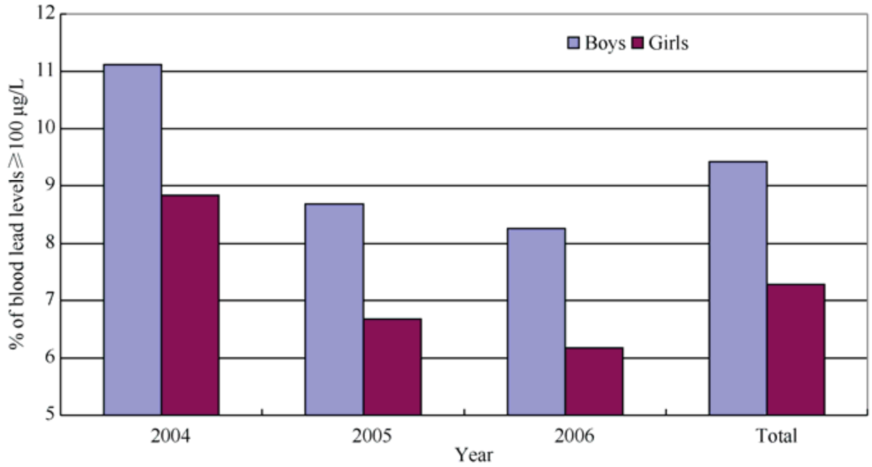

FIG. 2. Prevalence of elevated blood lead levels by gender.

The geometric mean of blood lead levels and the prevalence of elevated blood lead levels varied significantly by age and tended to increase with age (Figs. 3-4).

The city with the highest blood lead levels and prevalence of elevated blood lead levels was Hefei. The city with the lowest blood lead levels was Dalian and the city with the lowest prevalence of elevated blood lead levels was Qingdao (Figs. 5-6).

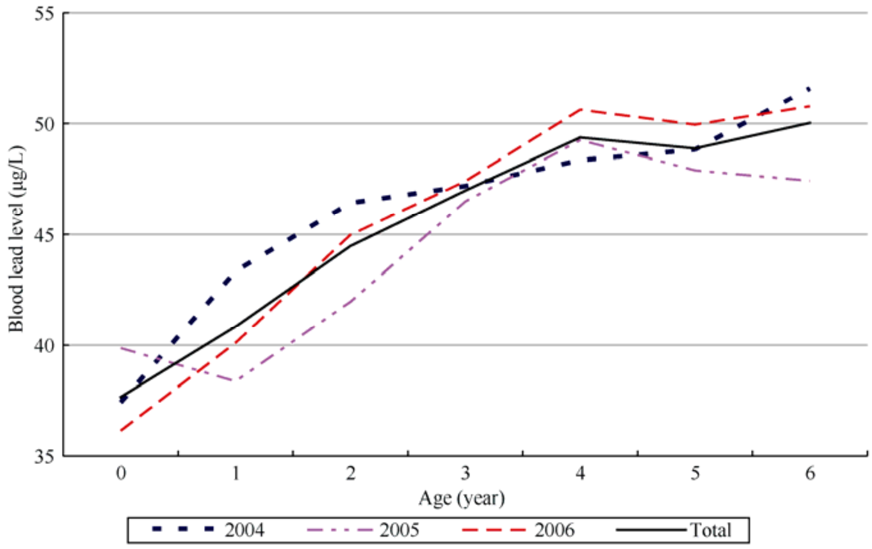

FIG. 3. Trend of blood lead levels by age.

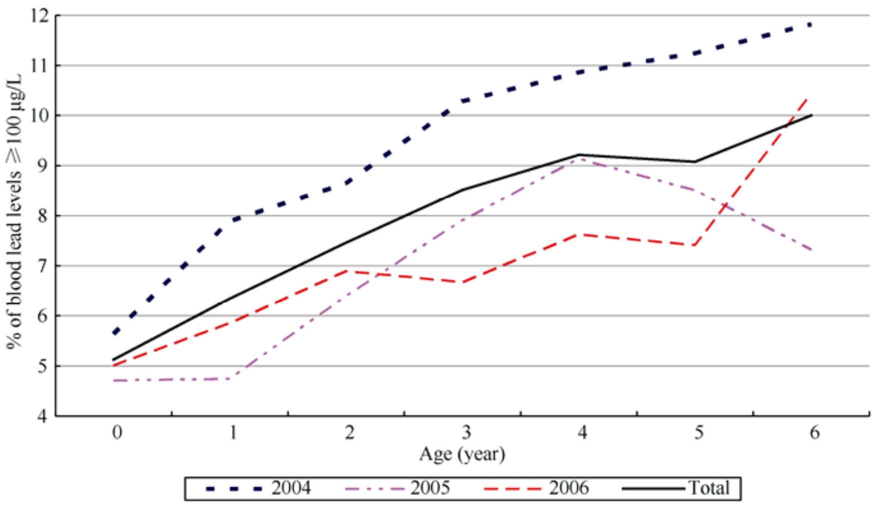

FIG. 4. Trend of elevated blood lead levels by age.

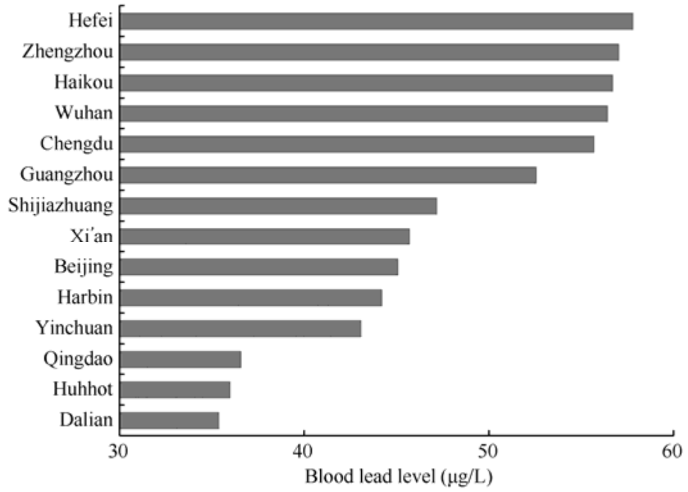

FIG. 5. Geometric mean of blood lead level by city.

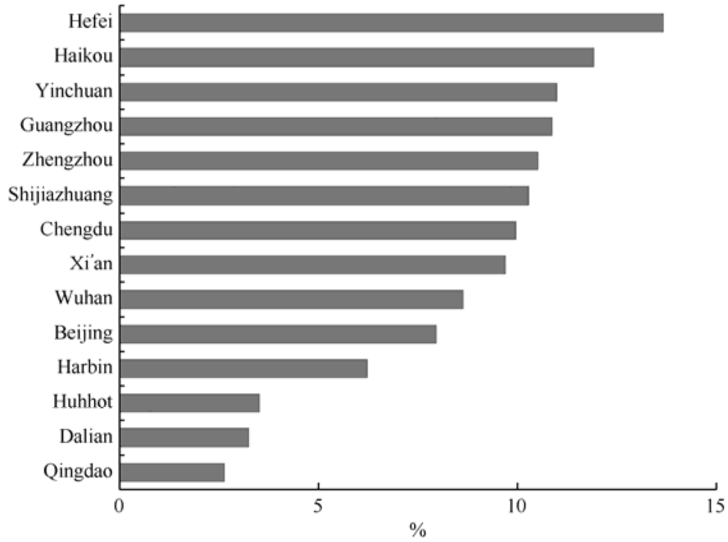

FIG. 6. Percentage of blood lead levels ⩾100 μg/L by city.

DISCUSSION

The geometric mean of blood lead levels in the 44 045 children aged 0-6 years under surveillance was 46.76 μg/L, with a 95% confidence interval of 46.48-47.04 μg/L. In accordance with the US CDC's definition of elevated blood lead level (⩾100 μg/L)[8], the prevalence of elevated blood lead levels in the total children under surveillance during the 3 years was 8.46%. The proportion with a blood lead level ⩾200 μg/L was 0.73%, similar to the 1988-1991 findings in the United States (0.6%) from Phase 1 of the Third National Health and Nutrition Examination Survey (NHANES III)[9-10]. There were 88 cases (0.20%) of severe lead poisoning in the children requiring chelation therapy (blood lead level ⩾ 450 μg/L).

There were significant differences in the mean blood lead level and prevalence of elevated blood lead levels by age. The geometric mean blood lead level trended to increase with age. The age distribution of blood lead levels in young children primarily reflects their behavior and environmental exposure sources. In the United States, blood lead levels are consistently higher in younger children than in older children because the predominant exposure source is lead in household dust from deteriorating paint, and it is more likely for younger children to ingest dust through normal hand-to-mouth contacts[10]. Typically, younger children are less likely than older children to be exposed to environmental lead outside the home because they are less mobile. As children grow older and spend more time in playing outdoors and attending school, they receive less exposure to lead sources within the home and more exposure to lead sources outside the home. However, the most important lead sources in China may be different from those in the United States. The trend of rising blood lead levels along with age was seen in the children under surveillance, suggesting that lead exposure comes primarily from outdoor sources rather than from indoor ones.

The mean blood lead level and the prevalence of elevated blood lead level in children under surveillance are lower than those reported in the Chinese media, but higher than those reported in developed countries. The blood lead levels vary widely in studies published in China. Results of many studies show that the prevalence of lead poisoning in children is very high. However, some studies showed that the prevalence of lead poisoning in children is not so high. Tow recent studies conducted in Nanchang (2004) and Beijing (2005) found elevated blood lead levels in 14.4% and 15.8% of studied children, with a mean blood lead level of 64.12 μg/L and 55.9 μg/L, respectively[11-12].

Several possible factors can lead to a significant difference in blood lead level. First, the extremely high prevalence of elevated blood lead levels is found in areas where lead exposure is thought to be unusually high. Second, China has begun to ban leaded gasoline all over the country since 2001 and changes in gasoline policy should have to be taken into account. Shanghai is the first city that has introduced lead free gasoline since 1997 and then corresponding studies in the next two years suggested that the average lead level in young children of Shanghai decreases significantly. The geometric mean blood lead level was dropped from 83 μg/L in 1997 to 76 μg/L in 1999) and the prevalence of elevated blood lead levels was deceased from 37.8% in 1997 to 24.8% in 1999[13]. Third, methodology is also a possible factor that might have contributed to different findings in various studies. Blood samples are easily contaminated with environmental lead unless stringent precautions are taken to clean subjects' hands thoroughly prior to drawing blood and to use materials that are prescreened to rule out lead contamination. In this study, all the staff members were trained for blood sample's collection, storage, transportation, and determination in advance. At all the sites of surveillance, the same operating procedures were required. All the materials were lead-free during blood collection. Quality control materials were used to minimize the potential for errors in laboratory findings. However, few papers on lead exposure published in China have mentioned the use of quality control materials or "lead-free" materials for blood collection. To the extent that any lead contamination of samples may occur in a study, findings may be biased upward. However, if quality control materials are not used, findings can be biased in either direction.

CONCLUSION

The blood lead levels in urban children of China are lower than those reported, but higher than those in developed countries. Childhood lead poisoning remains a public health problem in China. If possible, a nationwide population-based survey should be conducted to objectively assess blood lead levels in all children. It is important to develop and apply national standards for blood lead measurement and quality control. It is imperative to assess the problem realistically and soberly to develop sound and practical national guidelines for the prevention and treatment of childhood lead poisoning.

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