Letter to the Editor

A Systematic Assessment of Blood Lead Level in Children and Associated Risk Factors in China*

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In this study, we searched multiple databases for all relevant original articles (1996-2013). To investigate blood lead levels (BLL) and possible risk factors for lead exposure among children in China A total of 388 articles met our inclusion criteria. The overall geometric mean (GM) BLL was 71 μg/L, and the prevalence of elevated BLL (EBLL, defined as BLL ≥100 μg/L) was 18.48% among children. The prevalence of EBLL remained significantly higher among boys. In children less than 6 years of age, there were significantly increasing trends in both BLL and prevalence of EBLL in an age-dependent manner. The ban on leaded gasoline significantly reduced the BLL as well as EBLL prevalence; however, children whose parents had lower educational levels or were exposed to lead in the workplace had a higher EBLL prevalence. Despite its decline over time, the average BLL among children in China remains higher than the average level most recently reported in the United States. Childhood lead poisoning remains a public health problem in China.

Lead, a well-known toxic heavy metal, pervasively exists in the environment. It has a long environmental persistence and does not lose its toxicity if ingested[1]. People may be exposed to lead from a variety of sources, such as tap water, soil and dust, and foods contaminated during processing. Since the early 20th century, leaded petrol has caused more environmental lead exposure than any other source. Although the adverse health effects of lead exposure on children and adults are well documented, there is no agreement on a safe threshold for blood lead levels (BLL) in children[2].

Developing children are more sensitive to lead exposure owing to behavioral and physiological differences, as well as their higher rates of absorption and lower excretion. Indeed, there is increasing evidence showing adverse health effects of lead in children. Lead poisoning can affect nearly every system in the body, such as the nervous, hematopoietic, and excretory systems. The most sensitive target for lead toxicity is the nervous system, damage to which can sometimes be permanent. Additionally, lower BLLs (i.e., below 100 μg/L or even 50 μg/L) are associated with some behavioral problems such as attention-deficit/ hyperactivity disorders[3], increased likelihood of dropping out of high school, reading disabilities, lower vocabulary, lower class rank in high school, and increased risk for aggressive or violent behavior[4].

China is developing rapidly, and lead is widely used in the manufacturing industry. Some measures have been taken to control environmental lead pollution. In the 1990s, China began to ban the use of leaded gasoline. To date, BLL among children has been investigated in many provinces and cities across China; however, the findings have been inconclusive. The overall BLL of children in China has rarely been reported and is still not clear. We therefore conducted a systematic review of the literature to determine the BLL of children in China.

Statistical analyses were performed by using SPSS software (version 17.0 for Windows, SPSS Inc., Chicago, IL, USA), and the significance level was set to $P<0.05$.

Between 1996 and 2013, a total of 388 articles (Table S1, on the website of www.besjournal.com) were identified to meet the screening criteria; the studies involved 1,537,531 children aged 0-20 years. Among the retrieved articles, 275 reported BLL while

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269 studied EBLL prevalence. There were 185 articles concerning differences between the two sexes, of which 150 reported BLL and 139 reported EBLL prevalence. BLL as related to age was studied in 104 articles, and differences in the place of residence (urban *vs.* rural areas) were analyzed in 25 articles. The distributions of the sample sizes and numbers of reports according to the year of publication are shown in Figure 1. Investigation of lead levels in children begun in earnest after 2003.

Since the reports did not all use the same parameter to describe the blood load of lead, the BLL was reported as the arithmetic mean (AM), geometric mean (GM), and median (M); or otherwise EBLL prevalence.

The weighted AM BLL was 71 μg/L, GM BLL was 68 μg/L, and M BLL was 69 μg/L, ranging from 26 μg/L to 254 μg/L. According to the reference value of lead poisoning (BLL ≥100 μg/L), EBLL prevalence was 18%. Lead exposure in China, which is the largest developing country, is widely present, and the country is taking greater measures to deal with this problem. Compared to previous studies conducted in 2007[5] our results showed that BLL and EBLL prevalence decreased between 1996 and 2013. This indicated that measures taken to control lead exposure have been effective in China.

We also analyzed the changes in BLL and EBLL prevalence among children by sex and age, respectively. Reports with small sample sizes published before 2002 were all grouped together. The GM BLL was 112 μg/L before 2002, and declined to 50 μg/L in 2013. The EBLL prevalence declined by almost 40% between 1996 and 2013. Both BLL and EBLL prevalence in children declined over time for both sexes (P<0.05 for EBLL; prevalence trend test). Sex-specific analysis was conducted in 150 articles for EBLL prevalence and in 139 articles for GM BLL. Analysis showed that the weighted GM BLL was 59 μg/L in boys and 52 μg/L in girls. The prevalence of both BLL and EBLL was significantly higher in boys than in girls (P<0.05) (Figures 2A). This can be explained by behavioral differences[6]. Boys spend significantly more time outdoors than girls[7].

After reaching school age, the growth and development of children gradually plateaus with the maturation of the brain. Exposure to lead in children under 6 years is more harmful than exposure after this age. Thus, we were more concerned about BLLs of children under 6 years old. As shown in Figure 2B,

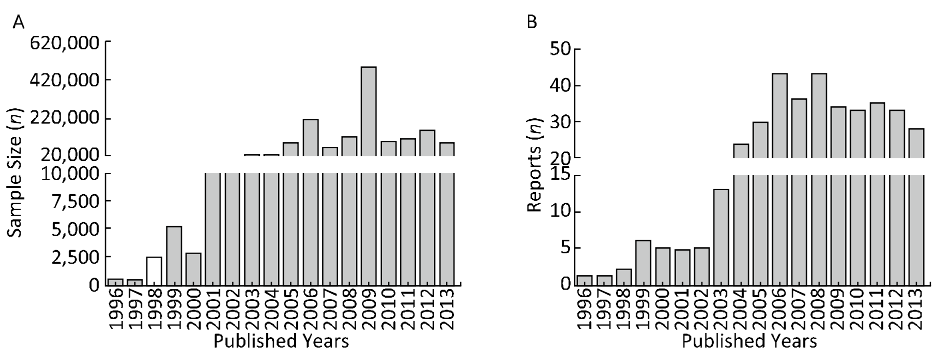

Figure 1. Distributions of the sample size and number of reports according to the year of publication. (A) Sample size; (B) Number of reports.

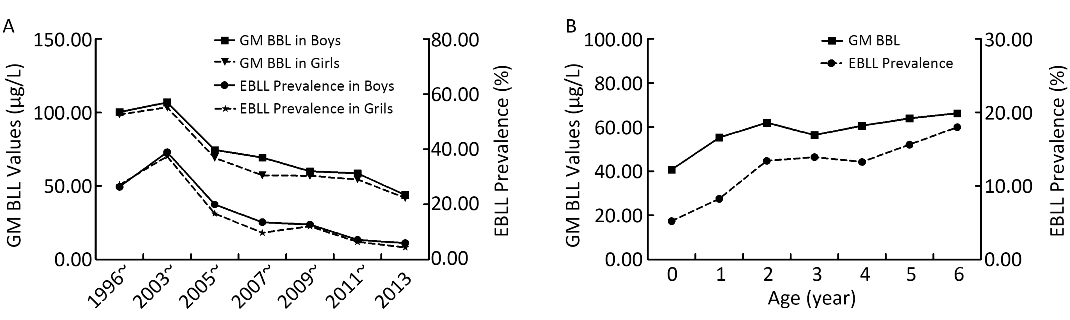

Figure 2. Changes in GM of BLL and EBLL prevalence by sex (A) and age (B).

the trends of both BLL and EBLL prevalence increased significantly in an age-dependent manner (*P*<0.001 for trend test). This phenomenon was also reported in other study[2]. Though there is a small peak at 2 years of age, the values are lower than those at 6 years of age for both weighted BLL and EBLL prevalence. This small peak might be because hand-to-mouth behaviors of children starts to decrease after the age of 3 years[7], which reduces the risks of children's intake of lead. As a child grows, his or her height also increases, and a height of 1 m from the ground is where lead is more likely to be concentrated in the air; this height corresponds to the breathing zone of 4-6 year old children.

Four and three articles described mothers' and fathers' educational levels, respectively. We divided educational levels into 3 subgroups: high (college degree or above), middle (high school/technical secondary school), and low (junior high school or below). As shown in Table 1, the higher the parents' educational level, the lower their children's EBLL prevalence. The differences in EBLL prevalence were statistically significant for both mothers and fathers. Generally, parents with higher educational levels have better awareness of lead poisoning, which is advantageous for training children in good health habits so that their exposure to lead can be reduced.

Three articles demonstrated a relationship between the children's EBLL prevalence and their parents' exposure to lead at the workplace. The combined results showed that the exposure of parents, and particularly of mothers, to lead in the workplace significantly increased the risk of lead exposure in their children (Table 1). A partial explanation could be that parents brought the lead from home via their clothes, hair, and hands, polluting the home environment[8].

As also shown on Table 1, children living in urban areas had significantly higher EBLL prevalence compared to those living in rural areas (*P*<0.05). As we known, the manufacturing industry, construction Industry and car exhaust in urban were more than them in rural, which affected the blood lead level of children.

China has banned the use of leaded gasoline since 2000. To explore the relationship of leaded-gasoline use to BLL and EBLL prevalence among children, we considered the sampling performed in 2000 as the cut-off. Table 1 showed that the use of leaded gasoline significantly increased BLL in both boys and girls. Changing to lead-free petrol reduced the EBLL prevalence by about 17% (*P*<0.05). Since January 1, 2000, all leaded-gasoline production in China has stopped. Qing et al.'s report also showed that automobile exhausts contributed to approximately 30% of the lead in the atmosphere between 1996 and 1997. This percentage was 20% between 2001 and 2002, and fell by 15% between 2002 and 2003[6]. So, this decrease in the EBLL prevalence might be attributable to the change to unleaded petrol. Even though the ban on leaded gasoline decreased children's mean BLL, lead persisted in these children's living environments for many years.

Five articles reported the relationship between BLL in children and seasons. Pooled results showed that the EBLL prevalence in children was higher in the summer. Children's BLLs also showed a distinct seasonal cycle (Table 1). It may be that there is increased

Table 1. Children's EBLL Prevalence by Parent or Environment Factors

Factor		*N*	EBLL Prevalence (%)
Educational level			
Mother	High	2,742	5.22
	Middle	3,091	7.38[a]
	Low	1,532	12.86[a,b]
Father	High	2,301	4.82
	Middle	2,397	6.47[a]
	Low	697	7.75[a]
Lead exposure at work			
Mother	No	6,330	5.53
	Yes	676	12.28[c]
Father	No	5,866	5.22
	Yes	1,130	8.58[c]
Areas			
Rural		15,694	13.51
Urban		21,918	16.20[d]
Leaded gasoline			
Boys	No	338,469	13.28
	Yes	1,713	30.10[e]
Girls	No	255,030	11.42
	Yes	1,632	28.75[e]
Seasons			
Spring		9,701	14.70[f]
Summer		10,711	16.39[f,g]
Autumn		7,742	13.30[h]
Winter		6,132	11.97

Note. [a]Compared to high educational level, *P*<0.05; [b]compared to middle educational level, *P*<0.01; [c]compared to no lead exposure at work, *P*<0.01; [d]compared to rural areas, *P*<0.05; [e]compared to unleaded gasoline (of the same sex); [f]compared to winter, *P*<0.01; [j]compared to spring, *P*<0.01; [h]compared to summer, *P*<0.01. EBLL: elevated blood lead level.

indoor and outdoor exposure to the lead in the dust and soil during the summer[9]. Other factors that may increase the seasonal exposure to lead include soil moisture, PM_{10} (which refers to particulate matter with an aerodynamic diameter ≤10 μm), and wind speed[10]. BLL may also be lower in the winter because the ground may be frozen or covered with snow/ice.

In conclusion, the mean BLL as well as EBLL prevalence among children in China has declined over time. However, the mean BLL is still higher than the latest United States reference value (50 μg/L) as updated in 2012. Controlling exposure to lead remains one of the government's most important tasks.

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