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Environmental Lead Exposure Among Children in Chengdu, China: Blood Lead Levels and Major Sources

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Abstract A survey was performed to know blood lead level (BLL) of children under seven and the risk factors of high BLL in Chengdu, China in 2004. The mean BLL in children under seven in Chengdu was 63.88 μg/L. The detection rate of high BLL was 8.21%. Chengdu is a moderate popular region of lead poisoning. Substitute of breast milk, living at the base floor or in one-storey houses and houses near the streets are the risk factors of high BLL ($p < 0.05$). The risk of anorexia, spasm and impaired concentration is higher in children whose BLL is higher than those whose BLL is lower ($p < 0.05$). Living circumstances, feeding patterns, and eating habits affect BLL, which in turn influences children's health status.

Keywords Blood lead level · Exposure · Children · China

Lead poisoning is one of the most significant environmental health threats that children face. Even low levels of lead exposure are associated with impairment of childhood cognitive function (Canfeld et al. 2003) and abnormal infant behaviour (Mendelsohn et al. 1999).

Over the past 30 years regulatory and environmental reforms in the developed world have significantly ameliorated lead pollution among children, while in developing countries, the extent of environmental lead and ways to reduce and prevent exposures are only beginning to be understood (Romieu et al. 1997; Alliance to End Childhood Lead Poisoning and Environmental Defense Fund 1994). Regulations designed to limit lead pollution are less common and less likely to be enforced compared with those in developed countries (Romieu et al. 1997). In China, children are exposed to lead from the industrial processes. To determine blood lead level (BLL) and its risk factors among children under seven and provide scientific evidence for prevention, Child Hygiene Cooperation Center of WHO in China carried out an investigation to monitor the BLL of children in 15 cities in China from 2004. Our group took charge of the study in Chengdu, the biggest city in southwest China.

This investigation is a large population-based study focusing on the health status of children under seven living in Chengdu, China. We collected biomarkers, including blood lead and child health datum points. Data were collected from 938 children to assess BLL and analyze the correlates. In this paper we describe the prevalence of lead poisoning among these children living in Chengdu and explore the correlation of lead toxicity.

Materials and Methods

Children under seven were eligible for inclusion in the study. A total of 938 subjects were included. Half of them were selected randomly from kindergartens and the other half were discharged from hospitals within the past 4–8 months. All of them answered the same questionnaire. All samples were collected when they came to the hospital.

Detailed information about health status was obtained from the questionnaire. Parents' occupation, inhabited

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environment, living habits, and health status were queried. Health measures included a general (child) health questionnaire, birth history, body height, body weight and blood tests for haemoglobin and lead. Medical technicians collected the questionnaire and physical health measures; project leaders monitored the data collection methods to ensure quality and uniformity.

Fasting venous blood samples of all subjects were obtained after a 30-min rest in a sitting position. Medical technicians obtained whole venous blood samples using standard techniques. All subjects' laboratory samples were analyzed for haemoglobin and lead. Haemoglobin was assessed from the whole venous blood sample collected in a Vacutainer tube (Becton–Dickinson, Franklin Lakes, NJ, USA) containing ethylenediaminetetraacetic acid–tripotassium salt (EDTA-K3). Blood lead was assessed from whole venous blood sample collected in a Vacutainer tube (Becton–Dickinson, Franklin Lakes, NJ, USA) containing heparin lithium. All tests were performed within 1 h of collection. All tests were done in the Department of Laboratory Medicine, West China Second University Hospital, Sichuan University, Chengdu, China. This laboratory subscribes to the National System of External Assessment of the Quality of Results and also to College of American Pathology (USA). Only widely accepted test kits were applied. Haemoglobin was assessed by a Sysmex XE-2100 Automated Hematology Analyzer (Sysmex, Japan) with the appropriate calibrator, reagent kits, and quality control processes. Blood lead was assessed by flame atomic absorption spectroscopy (AAS) using BH2100-type tungsten boat atomic absorption spectrometer manufactured by Beijing Bohui Chuangxin Photoelectric Technology Co., Ltd. Blood lead testing system was calibrated by Chinese Institute of Technology with atomic absorption standard reference materials. The daily internal quality control was done using Norway Seronorm™ Trace Elements Whole Blood quality control (LOTMR9607).

All the data from the questionnaires were input to EpiData database. Elevated BLL was defined as higher than 100 μg/L, conforming to current US Centers for Disease Control and Prevention (CDC 1991) and WHO guidelines (1995). All subjects signed informed consent. The investigation was carried out according to the principles of the Declaration of Helsinki. This project was registered with the Institutional Ethics Committee (West China Second University Hospital, Chengdu, China) under number 075/08.

All children who had complete questionnaire data with measured BLL were included in an exploratory analysis to determine the correlates. All analyses were performed with the Statistical Package of Social Sciences, Version 13.0 (SPSS, Inc., Chicago, IL, USA). Variance analysis was used to assess the difference of BLL in each age group. Logistic regression model was used to assess the risk factors of high BLL. Chi-square test was used to assess BLL clinical correlates. $p < 0.05$ was considered statistically significant.

Results and Discussion

We tested BLL in a total of 938 children. Of them, 77 (8.21%) had BLL > 100 μg/L. The mean BLL was 63.88 μg/L. The BLL increased with age (Table 1).

Substitute of breast milk, living at the base floor or in one-storey houses and houses near the streets are risk factors ($p < 0.05$), (Table 2).

Clinical correlates with elevated BLL – such as night terrors, biting stationery, impaired concentration, constipation, difficulty in learning, anorexia, and spasm – were assessed to determine possible association. Our result showed that anorexia, spasm and impaired concentration were significantly associated with increasing BLL ($p < 0.05$) (Table 3). We noticed that the blood haemoglobin concentration was inversely associated with BLL. Pearson Correlation coefficient $r = -0.075$ ($p < 0.05$).

Our result showed that 77 out of the 938 children (8.21%) living in Chengdu had elevated levels of lead in the whole blood. To assess the level of lead poisoning in children in each area, CDC of American divided the prevalence into three groups in 1997: (1) higher than 12%: high epidemic area; (2) 6%–12%: moderate epidemic area; (3) lower than 5.9%: low epidemic area. Chengdu is a moderate epidemic area according to the criterion. There

Table 1 BLL in each age group

Age group (years)	High BLL/total subjects	BLL $\bar{x} \pm$ SD (μg/L)	BLL variance analysis (F value)
0–	3/108	48.38 ± 21.69	9.343**
1–	6/101	60.53 ± 24.94	
2–	3/96	58.81 ± 19.63	
3–	24/193	68.07 ± 28.38	
4–	16/178	68.89 ± 23.88	
5–	17/171	66.04 ± 25.91	
6–7	8/91	70.20 ± 29.43	

** $p < 0.01$

Table 2 Logistic regression model of risk factors of high BLL

Variables	Coefficient	Wald	OR	95% CI
Houses beside the streets	0.653	6.214**	1.921	1.150–3.211
Feeding patterns		5.408		
Breast milk	0.596	1.236	1.816	0.634–5.196
Substitute of breast milk	−0.648	2.880*	0.523	0.247–1.106
Mixing	0.183	0.146	1.201	0.470–3.066
Animal milk	−0.009	0.001	0.991	0.484–2.029
Canned food	0.123	0.081	1.131	0.486–2.635
Calcium medicament	0.226	0.782	1.254	0.759–2.070
Puffed food	0.052	0.039	1.053	0.630–1.759
Living scattered	0.071	0.065	1.073	0.623–1.849
Living at the base floor or in one-storey houses	0.614	4.273**	1.848	1.032–3.309

* $p < 0.05$, ** $p < 0.01$

Table 3 BLL clinical correlates

Clinical correlates	Subjects with clinical correlates/subjects with high BLL	Subjects with clinical correlates/subjects with low BLL	χ^2
Anorexia	31/77	244/861	4.847*
Spasm	7/77	30/861	5.864*
Biting stationery	23/77	177/861	3.654
Constipation	18/77	202/861	0.000
Difficulty in learning	20/77	168/861	1.842
Impaired concentration	52/77	402/861	12.294**
Night terrors	20/77	231/861	0.026

* $p < 0.05$, ** $p < 0.01$

are about 10 million people in Chengdu, 10% of whom are children. This means about 821,000 children had elevated blood lead. Substitute of breast milk, living at the base floor or in one-storey houses and houses near the streets are risk factors ($p < 0.05$). It is a valuable evidence to control lead exposure in children.

We found that BLL increased with age. The BLL of babies under one was the lowest, while BLL in children above three was higher. The reason may be that the chance of contacting soil increased gradually after 1-year-old. The absorptivity of lead in children was 5–10 times higher than that in adults, but the excretory rate of lead in children was lower than that in adults, which resulted in lead accumulation in Children. This accorded with data recommended by Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) (Bloch et al. 2000). So, lead screening in children is strongly recommended every year from three on. There is no evidence that BLL below a threshold is harmless. So children will benefit from any protective measures to reduce lead exposure.

Lead is an anthropogenic neurotoxicant now widely dispersed around the world. Its presence in toxic concentrations among children seems to closely follow economic and industrial development (Flegal and Smith 1992). Accordingly, careful environmental, societal and economic assessments of environmental lead exposure are important. Successful childhood lead-poisoning prevention programmes in other countries can serve as models for regulating anthropogenic lead pollution and enforcing existing laws in China.

Our result showed that anorexia, spasm, and impaired concentration were associated significantly with increasing BLL and that the blood haemoglobin concentration was inversely associated with BLL. So, those who have clinical manifestations mentioned above should be screened to help early intervention.

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