SCREENING OF SCHOOL CHILDREN FOR BLOOD LEAD LEVELS AND ATTEMPTS TO REDUCE THEM BY NONPHARMACOLOGICAL MEANS IN A COASTAL CITY OF INDIA

VISHWANATH PRASHANT, AKILA PRASHANT, D. DEVANAND, NAYAK NARENDRA, D'SOUZA VIVIAN, T. VENKATESH[1]

ABSTRACT

CONTEXT: ***Lead is a major health hazard, especially in children. Impact of lead poisoning on our society is not known. Effectiveness of environmental interventions in reducing blood lead levels is not exactly known, though the Center for Disease Control and Prevention strongly advocates use of such means. AIMS: We aimed at screening school children for blood lead levels (BLLs) and reducing the BLLs of children with preliminary BLL >20 µg/dL by environmental intervention and intensive education. MATERIALS AND METHODS: To assess the extent of lead poisoning, a screening of 106 children was done, which showed that children belonging to a particular government primary school had higher BLLs. A second screening program of 87 children conducted in that school showed that only 19% had BLL <10 µg/dL; whereas 44% had BLL between 10 and 20 µg/dL, and 37% had BLL >20 µg/dL. Thirty-eight children having BLL >20 µg/dL were selected from the two screening programs. After removing all potential sources of lead from their environment and educating them about the ways to prevent exposure to lead, follow-up of their BLLs was carried out at an interval of 6 months for a period of 1 year. STATISTICAL ANALYSIS: Values of the different follow-up studies were compared using repeated-measure ANOVA. RESULTS: Our results showed that there was a significant (P <0.0001) reduction in the BLLs in the first and second follow-up studies. CONCLUSIONS: The study is a proof of the concept that a decline in the BLLs can be achieved by intense education and avoiding the potential environmental sources of lead.***

Key words: Anode stripping voltammetry, blood lead levels, nonpharmacological means

INTRODUCTION

Lead is ubiquitous in the environment as a result of industrialization. The use of lead-containing paints and leaded petrol has been accountable for a gradual accumulation of lead wastes in recent times, resulting in overall increase of lead absorption.[1,2] The awareness of people about lead being a source of toxicity is mainly limited to petroleum products. Very few have knowledge of domestic sources of lead, such as paint, water, and soil.[3]

Undue exposures to lead, particularly among young children, have remained a public health problem for decades.[4] Today it rarely results in severe symptoms, but there is growing evidence that unwarranted exposure even with blood lead concentrations below those usually associated with symptoms can lead to poor classroom performance,[5] impaired educational performance,[6] inattention and hyperactivity,[7] juvenile delinquency,[8] impaired motor development,[9] behavioral problems,[10] and lower IQ levels.[11] Although the Center for Disease Control and Prevention (CDC) has set a 'level of concern' at blood lead concentration of 10 µg/dL, a threshold below which lead has no toxic effects has not been demonstrated, and recent studies have extended the level to <10 µg/dL.[12,13]

Children and adults differ in the relative risks of sources, metabolism, and the ways in which toxicities are expressed.[14] The average gastrointestinal absorption of lead is much greater in infants and young children than in adults,[15] and the absorption is increased in the presence of nutritional deficiencies that are more common in children than in adults, e.g., deficiency of iron.[16,17]

Interventions such as peer education; emphasizing dust control through household cleaning; teaching hygiene such as hand washing; increasing awareness about nutrition; and behavioral changes such as removing shoes at the door and letting the water flow reduced the risk of an elevated blood lead level. Some authors have achieved a 34% decline in BLLs by environmental intervention alone.[18,19]

The presence of the problem of lead poisoning has only been recently acknowledged in India. Insufficient data on the lead problem, unawareness of lead being a poison, and very few initiatives to deal with elevated blood lead levels add to the intricacy of the problem. In the present study, an attempt has been made to lower the blood lead levels of children identified to have an initial blood lead level (BLL) >20 µg/dL, by trying to identify and remove all possible sources of lead from the child's environment.

MATERIALS AND METHODS

Study group

A screening of BLLs of 106 children belonging to different schools and representing different classes of society was done. This screening showed that children belonging to a particular government primary school had higher lead levels when compared with their peers. A second screening program of 87 children was conducted in that school. It was found that only 19% had BLL <10 µg/dL, 44% had BLL between 10 and 20 µg/dL, and the remaining 37% had BLL >20 µg/dL. Forty-one children having BLL >20 µg/dL were selected from the two screening programs and divided into two age groups of 7 to 10 years and 11 to 13 years. Three children dropped out of the study (left the school). Among the 38 children, a comparison of the results was done between the children of two age groups and between male and female children.

Sample collection

Parental consent was obtained before drawing blood samples from the children. The study was approved by the ethical committee review board of the institution. Fifty microliters of capillary blood was collected in graduated capillary tubes. The collected blood was immediately

Department of Biochemistry, Kasturba Medical College, Mangalore, India [1]St. John's National Academy of Health Sciences, Bangalore, India

Correspondence:
Dr. Prashant Vishwanath
Department of Biochemistry, JSS Medical College, Mysore, India. E-mail: mvps@rediffmail.com

transferred to the blood diluent reagent provided with the kits. Blood collection was done three times at 6-month intervals including the initial screening to monitor the BLLs.

Instrument

Lead care analyzer [Environmental Science Associates (ESA Inc., USA)] was used to estimate the BLLs. This uses anode stripping voltammetry (ASV) method[20] for measuring the BLL. Whole blood was added to the reagent solution. Any lead present was released from the blood components. Then, lead in the reagent solution was concentrated into a thin-film electrode during the plating step of the analysis cycle. The plated lead was removed from the electrode by applying a stripping current, and the amount of lead was measured by integration of the electric current released during this rapid electrochemical step. The current released during the stripping step was directly proportional to the amount of lead present in the blood sample.

Sources of lead

The sources of lead in a child's environment were investigated using x-ray fluorimeter (XRF), 700 series NITON Corporation. In some cases, it was possible to identify one potent source of lead (e.g., fishing net weights, leaking lead acid battery at the residence, or medicine of unknown constituents); while in some cases, it was a mixture of multiple sources (e.g., diet, lead-based paints, and dust from contaminated leaded paint). However, the most potent single source of lead was found to be lead-based paints.

Environmental intervention or nonpharmacological means to reduce BLLs

In this 1-year follow-up interventional study, the first values of BLLs were considered as baseline values after which intervention was sought. Environmental intervention was done based on the following guidelines:[21]

1. Determining the most likely sources of high-dose exposure to lead and its removal from the child's environment
2. Investigating the child's home to identify sources of lead, including both interior and exterior environment, giving special attention to painted surfaces, dust, soil, and water
3. Educating parents, caretakers, and teachers about identified and potential sources of lead and ways to reduce exposure
4. Providing lead-free drinking water
5. Abatement of paints from the children's park where most of these children played

The guidelines prescribed by CDC for case management of children with BLLs ranging from 20 to 44 μg/dL (class-2) and from 44 to 69 μg/dL (class-3) were used in the study. For class-3 children, pharmacological intervention was not considered as these children did not show any visible symptoms associated with lead poisoning.[22]

All possible sources of lead in the school and residences of the children were removed. Intensive education about lead-poisoning prevention and control measures was imparted to parents, children, and teachers of the government primary school. The teachers used to monitor the day-to-day activity of these children. Repeated visits to the residences of these children ensured that they were not exposed to any lead sources.

The children's parks were repainted with paints containing acceptable levels of lead. Parents were advised to clean their houses with wet mops. Specially designed and manufactured water filters [Filtrex India Ltd. and Eureka Forbes Ltd.] were provided to these children. These water filters could filter lead in the drinking water, and their efficacy in this aspect was tested by an ESA 3010B trace metal analyzer at National Referral Center for Lead Poisoning in India (NRCLPI). With the help of these water filters, lead-free drinking water was made available to the children. Parents were explained the use of these water filters and instructed to regularly clean the candles and filters. The candles were replaced once every 6 months. Children were provided with water bottles to carry this water to school and playgrounds. Along with lead, these filters could filter out microbial organisms and suspended particles, which prevented the children from acquiring waterborne diseases. The key factors behind environmental intervention were periodic follow-ups and education.

These children were also supplemented with iron and folic acid provided by the Government of India for students of all primary and higher primary schools. Incidentally a mid-day meal program was initiated in the school during the study period, whereby children were provided with at least one-third of their daily calorie requirement and half of their daily protein need. This ensured a good nutritional diet being provided to the children, and the compliance was monitored by the class teachers.

Statistical analysis

The data was collected and tabulated. Statistical analysis was done using computer software SPSS, version 12.0.1. The results were summarized into mean and SD. Values of the different follow-up studies were compared using repeated measures ANOVA since the same analyte was being measured repeatedly in the same population. At 95% confidence interval, a *P* value of < 0.05 was taken as significant.

RESULTS

The number of males and females in the first screening, second screening, and the study group; as well as the number of children with BLL <10 μg/dL, 10 to 20 μg/dL, and >20 μg/dL are given in Table 1. In the study group, the number of male subjects (n = 25) were greater than the number of female subjects (n = 13), and the number of children in the age group 7 to 10 years (n = 26) was more than the number of children in the age group 11 to 13 years (n = 12). The mean BLLs in the initial screening, first follow-up, and second follow-up in males and females and in the two age groups are given in Table 2. The values declined significantly in both males and females (P < 0.0001) in the first follow-up. There was a further decline in the mean BLLs in both the groups in the second follow-up, which was done 6 months after the

Table 1: Distribution of study subjects according to gender, age, and blood lead levels

	Males	*Females*	*7-10 Years*	*11-13 Years*
Screening I (n*=106)	50	56	33	73
Screening II (n=87)	50	37	60	27
Study group (n=38)	25	13	26	12
BLL†	**< 10 μg/dl**	**10-20 μg/dl**	**>20 μg/dl**	
Screening I	23	36	47	
Screening II	17	38	32	
Study group	-	-	38	

*n = total no of children, †BLL = blood lead level

Table 2: Blood lead levels in the initial screening and first and second follow-up compared in males and females and in the two age groups

Gender	*N**	*Initial Mean ±SD*†	*Follow-up 1 Mean ±SD*	*Follow-up 2 Mean ±SD*
Males	25	32.26±11.34	13.27±4.80‡	7.88±3.32‡
Females	13	32.27±10.23	11.79±6.85‡	5.64±3.38‡
Age group in years				
7-10	26	29.99±9.60	12.37±6.34‡	6.78±3.80‡
11-13	12	37.16±13.15	13.50±3.26‡	7.85±2.62‡
Total	38	32.26±11.34	12.75±5.60‡	7.18±3.49‡

*n = total number of subjects, †SD = standard deviation, ‡P < .0001

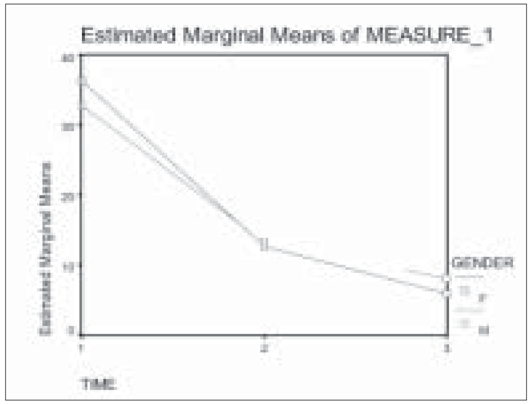

Figure 1: Fall in blood lead levels during the study period, compared in males and females

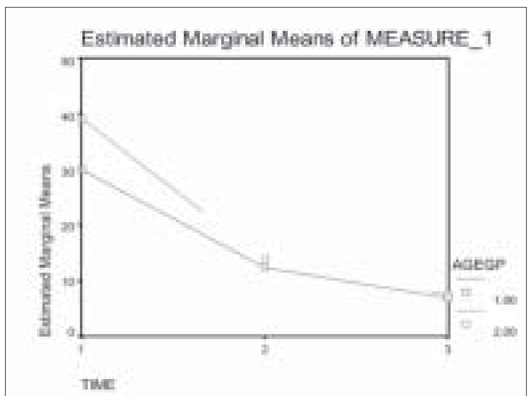

Figure 2: Fall in blood lead levels during the study period compared in the two age groups

first follow-up study (P < 0.0001) [Table 2]; whereas there was no significant difference in the pattern of fall of BLLs between males and females [Figure 1].

There was no statistically significant difference in BLLs of children in the age group 11 to 13 years when compared with the children in the age group 7 to 10 years. The decline in BLLs was significant in both age groups (P < 0.0001) in the first follow-up, when compared to the initial screening. Also the decline in BLLs in the second follow-up when compared to that in the first follow-up in both the age groups was significant (P < 0.0001), but no difference in the pattern of fall of BLLs was seen between the two groups [Figure 2].

The main sources of lead identified were yellow-colored paints, which had a mean lead concentration of 3.3 mg/cm^2; followed by orange paints, which had a mean lead concentration of 2.4 mg/cm^2. (Acceptable level in lead-based paints is <0.7 mg/cm^2).[22] Lead rings used in fishing nets used to be stored in the residences of some children, which left traces of the metal on the floor, leading to high lead levels in the dust swipes of the residences of these children. The floor lead readings in the residences of these children ranged from 81 ppm to 894 ppm (acceptable <200 ppm).[22]

DISCUSSION

The present study is a proof that significant reduction in BLLs of children can be achieved by environmental intervention to reduce the exposure to the heavy metal lead. Although many authors and studies have appreciated the positive role of environmental

intervention,[23] only some have practically demonstrated its effectiveness and its impact on BLLs.[18,19] The previous studies have achieved a 34% reduction in BLLs by environmental interventions.[19] Our study supports their hypothesis that a significant reduction in BLLs can be achieved by environmental interventions alone. A reduction in lead burden can prevent long-term complications associated with lead and improve overall health of children.

Environmental intervention was done based on guidelines prescribed by the Center for Disease Control and Prevention.[22] In addition to this, effective implementation of giving iron supplements provided by the Government of India for all primary schools was ensured as lead has a known inverse relation with hemoglobin.[17] The effectiveness of environmental intervention was measured by periodic BLL estimation.

The study group consisted of more number of male subjects (n = 25) as compared to female subjects (n = 13). Male children have fewer restrictions in an Indian society and hence an increased tendency to explore their environment; and in this process, they may be exposed to lead. The study also compares BLLs of children in two age groups (7-10 years and 11-13 years). Children aged 11-13 years showed higher BLLs when compared to children of younger age groups, though it was not statistically significant. Increase in age as a risk factor for elevated BLLs has not been reported from many countries. There are some studies from Mexico,[24] Bangladesh,[25] and Russia[26] that have reported a significant trend with increasing age above the age of 4 years. However, these results are in contrast with reports from United States,[27] where BLLs were the highest in 1 to 2 years old children. One possible explanation for this discrepancy in age trends is that factors that make younger children more susceptible to lead exposure (i.e., hand to mouth behavior, lead absorption physiology, etc.) may be superseded by other risk factors such as increased environmental exposure through outdoor activities or malnutrition.

Our study also shares the view that the number of children affected with lead poisoning is higher among children from the socially and economically challenged states. All the children in the study group were from a government higher primary school, and they were selected after an initial screening of 193 school children from different socioeconomic strata.

The strength of the study is that the study measures the BLLs after an environmental intervention and reports that significant reductions can be achieved by a combination of factors such as intense education, removal of all possible sources of lead from the environment, and effective monitoring of the affected children. The limitations of the study are that the sample size consisted of only school-going children. The study could have had a peer group without intervention to compare the results. The nutritional status of the children could have been studied along with BLLs. However, the study gives a direction in which further research can be done, especially in the Indian population.

ACKNOWLEDGMENT

We are deeply indebted to Mr. Bommi Govind of Filtrex India Ltd. for sponsoring this study and for donating the lead care analyzer (ESA Inc.) to the department. The initial screening program was funded by Karnataka State Pollution Control Board (KSPCB), Mangalore, India. We are grateful to Prof. Clark Scott, Environmental Health Engineer from the University of Cincinnati, U.S.A., for making the x-ray fluorimeter available to us. We thank Dr. A. Rajeev, Department of Community Medicine, Kasturba Medical College, Mangalore, for his contribution in screening programme.

REFERENCES

1. U.S. Environmental Protection Agency. Prohibition on gasoline containing lead or lead additives for highway use. Final Rule 61. Federal Register 1996; 3832-38 (Codified at 40 CER § 80).
2. Lead-based Paint Poisoning Prevention Act of 1971, as amended by the National Consumer Information and Health Promotion Act of 1976; 42 USA § 4821 et. Seq.
3. Adebamowo EO, Agbede OA, Sridhar MK, Adebamowo CA. An examination of knowledge, attitudes and practices related to lead exposure in South Western Nigeria. BMC Public Health. 2006;6:82.
4. Lin-Fu JS. Undue absorption of lead among children: A new look at an old problem. N Engl J Med 1972;286:702-10.
5. Needleman HL, Gunnoe C, Leviton AS, Reed R, Heresie H, Marker C, *et al*. Deficits in psychologic and classroom performance. N Engl J Med 1979;300:689-95.
6. Levinton A, Bellinger D, Allred EN, Rabinowitz M, Needleman HL, Schoenbaum S. Pre and postnatal low-level lead exposure and children dysfunction in school. Environ Res 1993;60:30-43.
7. Tuthill RW. Hair lead levels related to children's classroom attention deficit behaviour. Arch Environ Health 1996;51:214-20.
8. Needleman HL, McFarland C, Ness RB, Frenberg SE, Tobin MJ. Bone lead levels in adjudicated delinquents: A case control study. Neurotoxicol Teratol 2002;24:711-7.
9. Altmann L, Sveinson K, Kramer U, Winneke G, Wiegand H. Assessment of Neurophysiologic and neurobehavioural effects of environment in 5- and 6-year old children. Environ Res 1997;73:125-31.
10. Wasserman GA, Staghezza-Jaramillo B, Shrout P, Popovac D, Graziano J. The effect of lead exposure on behaviour problems in preschool children. Am J Public Health 1998;88:481-6.
11. Chen A, Cai B, Dietrich KN, Radcliffe WJ. Lead exposure, IQ, and behavior in urban 5- to 7- year olds: Does lead affect behavior only by lowering IQ? Paediatrics 2007;119:e650-8.
12. Lanphear BP, Hornung R, Khoury J, Yolton K, Baghurst P, Bellinger DC, *et al*. Low-level environmental lead exposure and children's intellectual function: An international pooled analysis. Environ Health Perspect 2005;113:894-9.
13. Canfield RL, Henderson CR Jr, Cory-Slechta DA, Cox C, Jusko TA, Lanphear BP. Intellectual impairment in children with blood lead concentrations below 10µg per decilitre. N Engl J Med 2003;348:1517-26.
14. Bellinger DC. Lead - Supplement article. Paediatrics 2004;173:1016-22.
15. Zeigler EE, Edwards BB, Jensen RL, Mahaffey KR, Fomon SJ. Absorption and retention of lead of infants. Paediatr Res 1978;12:29-34.
16. Bradman A, Eskenazi B, Sutton P, Asthanasoulis M, Goldman LR. Iron deficiency associated with higher blood lead in children living in contaminated environments. Environ Health Perspect 2001;109:1079-84.
17. Ahamed M, Singh S, Behari JR, Kumar A, Siddiqui MK. Interaction of lead with some essential trace metals in the blood of anemic children from Lucknow, India. Clin Chim Acta 2007;377:92-7.
18. Jordan CM, Yust BL, Robison LL, Hannan P, Deinard AS. A randomized trial of education to prevent lead burden in children at high risk for lead exposure: Efficacy as measured by blood lead monitoring. Environ Health Perspect 2003;111:1947-51.
19. Rhoads GG, Ettinger AS, Weisel CP, Buckley TJ, Goldman KD, Adgate J, *et al.* The effect of dust lead control on blood lead in toddlers: A randomized trial. Pediatrics 1999;103:551-5.
20. Morrell G, Giridhar G. Rapid micro method for blood lead analysis by anodic stripping voltammetry. Clin Chem 1976;22:221-3.
21. CDC. Managing elevated BLLs among young children: recommendations from the Advisory Committee on Childhood Lead Poisoning Prevention. Atlanta, GA: US Department of Health and Human Services, CDC; 2002. Available from: http://www.cdc.gov/nceh/lead/CaseManagement/caseManage_main.htm.
22. CDC WONDER. Preventing Lead Poisoning in Young Children: Time Frames for investigations and interventions. US Department of Health and Human Services, Public Health Services, Centers for Disease Control. 1991. Chapter 8: p. 63-4.
23. Fast AB, Mitra J, Kumar NS, Flora SJ, Avila MH, Carroll A, *et al*. A panel discussion on educating a low literacy population. In, Proceedings of the International Conference on Lead Poisoning Prevention and Treatment. Feb 8-10. Bangalore, India. 1999. p. 251-8.
24. Romieu I, Palazuelos E, Meneses F, Hernandez-Avila M. Vehicular traffic as a determinant of blood-lead levels in children: A pilot study in Mexico City. Arch Environ Health 1992;47:246-9.
25. Kaiser R, Henderson AK, Daley WR, Naughton M, Khan MH, Rahman M, *et al*. Blood lead levels of primary school children in Dhaka, Bangladesh. Environ Health Perspect 2001;109:563-6.
26. Rubin CH, Esteban E, Jones R, Noonan G, Gurvich E, Utz S, *et al*. Childhood lead poisoning in Russia: A site specific pediatric blood lead evaluation. Int J Occup Environ Health 1997;3:241-8.
27. Brody DJ, Pirkle JL, Kramer RA, Flegal KM, Matte TD, Gunter EW, *et al*. Blood lead levels in the US population: Phase 1 of the third National Health and Nutritional Examination Survey (NHANES III, 1988 to 1991). JAMA 1994;272:277-83.

Source of Support: 1. Mr. Bommi Govind of Filtrex India Ltd. sponsored this study and donated the Lead Care Analyzer (ESA Inc.) to the department. 2. The initial screening program was funded by Karnataka State Pollution Control Board (KSPCB), Mangalore, India. 3. Prof. Clark Scott, Environmental Health Engineer from University of Cincinnati, U.S.A., made the x-ray fluorimeter available to us.
Conflict of Interest: None declared.