ORIGINAL RESEARCH

Association between blood lead levels and environmental exposure among Saudi schoolchildren in certain districts of Al-Madinah

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Introduction: Both occupational and environmental exposures to lead remain a serious problem in many developing and industrializing countries. When humans are exposed to high levels of lead, there is damage to almost all organs and organ systems (most importantly, the central nervous system, kidneys, and blood), which often culminates in death.

Objective: To estimate the prevalence of blood lead levels (BLLs) and to identify the sources of environmental exposure and potential risk factors for elevated BLLs among Saudi schoolchildren.

Methods: A cross-sectional survey was conducted from March to May 2010. The study population included 557 Saudi school students of both sexes. A multistage random sampling technique was used. Information about socioeconomic status, house and school construction, and parents' education and employment was collected using questionnaires. Lead was analyzed in a blood sample using an atomic absorption technique and hemoglobin was measured using a Sysmex hematological analyzer.

Results: The mean BLL was 4.94 ± 3.38 µg/dL (range 0.45–26.3 µg/dL). A total of 19% had BLLs <1.0 µg/dL, 16% had BLLs <2.5 µg/dL, 15% had BLLs <5.0 µg/dL, 20% had BLLs <7.5 µg/dL, 25% had BLLs <10.0 µg/dL, and about 6% had BLLs >10.0 µg/dL. Analysis of odds by controlling all risk factors (adjusted odds ratio [OR]) that affect BLLs ($\geq$10 µg/dL) indicated that using cosmetics (OR = 18.5, confidence interval [CI] = 14.4–19.8), putting colored toys in mouth (OR = 15.7, CI = 3.6–16.2), eating canned food (OR = 9.8, CI = 7.0–10.1), and using newspaper during food preparation (OR = 7.6, CI = 6.3–8.2) are risk factors. There were significant correlations between BLLs and family habits (r = 0.225, $P = 0.000$), personal habits (r = 0.321, $P = 0.000$), eating habits (r = 0.128, $P = 0.002$) and school building characteristics (r = 0.469, $P = 0.000$). There was a significant correlation between BLLs and anemia in age group 6 < 12 years ($P = 0.000$) and age group 12 to less than 18 years, among males ($P = 0.000$) and females ($P = 0.041$).

Conclusion: The BLLs of children are affected by multiple factors. Female students have higher BLLs and lower hemoglobin concentration than males. The possible sources of lead exposure were use of toothpaste, use of kohl, putting colored toys in the mouth, use of both canned food and canned juice, use of lip gloss in females, and different methods of handling newspaper while preparing food.

Keywords: blood, lead, exposure, cosmetics, schoolchildren, anemia

Introduction

Lead is a metal that has been associated with human activities for the past 6000 years. That lead is an environmental toxin is an ancient observation. Despite increased attention, lead poisoning is still a serious problem. Lead is a ubiquitous environmental

and industrial pollutant that has been detected in every facet of environmental and biological systems.[1,2] Lead is a major industrial byproduct and can be found in water pipes, insecticides, linings of equipment where corrosion resistance and pliability are required, petroleum refining, construction, bullets, and X-ray and atomic-radiation protection equipment. The manipulation of lead for these uses has caused lead contamination of air, dust, and soil. Lead has been known to cause mental retardation and learning disorders.[3,4] Further sources of lead exposure include automobile emissions from use of leaded gasoline, industrial emissions, cottage industries (eg, battery recycling), lead-soldered cans and water pipes, lead-glazed ceramics, and traditional medicines.[5,6] Lead exposure may occur in the home (eg, paint, dust, and soil), workplace, other environments (eg, parents' occupation and hobbies), or from the use of folk remedies containing lead.[7,8] Further, lead exposure may occur through ingestion of flaking lead paint and inhalation of dust and soil contaminated with such paint (Table 1).[9]

Lead poisoning in adults occurs more frequently from exposure in the workplace and primarily involves the central nervous system (CNS). Children are more susceptible to lead exposure than adults because they participate in age-appropriate behaviors and activities that result in greater exposure, causing them to absorb more lead than adults and their overall development is also affected.[10] Children absorb 40%–50% of dietary lead and retain 2%–25%, whereas adults absorb 5%–10% and retain little.[11] Furthermore, children's digestive systems absorb lead more readily than an adult's system, and their premature and still-developing CNS is more vulnerable to lead toxicity than a mature CNS.[1,12] Lead is a pervasive environmental toxin that affects virtually every system in the body. Evidence of harmful effects in various organs has been found in children whose BLLs exceed 10 µg/dL.[13]

In 2000, an estimated 120 million people around the world had blood lead concentrations of between 5 and 10 µg/dL, and about the same number had concentrations of >10 µg/dL. Forty percent of all children had blood lead concentrations of >5 µg/dL, and half of these had blood lead concentrations of >10 µg/dL; of these children, 97% were living in developing countries.[14] Estimates published recently suggest that the theoretical minimum risk of health effects may occur at blood lead concentrations as low as 0–1 µg/dL.[14,15] Blood lead concentrations are indicative of recent lead exposure (within the preceding few weeks) rather than of cumulative long-term exposure. However, exposure to lead varies relatively little over the period

Table 1 Possible sources of lead[6–10]

Occupational	Environmental/Other
Painters	Lead-based paint (pre-1978)
Home remodelers/renovators	Soil/Dust near lead industries, roadways,
Construction/Demolition workers	Plumbing and solder
Bridge maintenance/repair	Cosmetics and hair dye
Auto body repairers/painters	Imported vinyl mini-blinds
Battery manufacturers/recyclers	Imported ceramic tiles for the kitchen/bathroom
Radiator repairers/manufacturing	Building materials
Furniture refinishers	Gutters, flashings, tiles, window glazing
Plumbers, pipe fitters	Ceramic ware/glazed pottery
Roofers	Porcelain bathtubs
Lead miners, smelters, and refiners	Leaded glass/pewter
Glass, copper and brass manufacturers	Leaded gasoline (race, collector cars)
Boat builders/painters/repair/ maintenance	Soldered seams-imported canned food
Ceramics making/Glaze mixing	Soldered copper pipes
Printers (ink)	Submersible pumps in wells
Plastic and rubber manufacturers	Brass plumbing fixtures
Police officers	Bronze, pewter, leaded crystal
Firing range instructors	Electronics manufacturers Pesticides
Steel welders or cutters	Storage batteries
Jewelry making	Plastic insulation on electrical wiring and old telephone wiring
Gas station attendants	**Ingested sources**
Aircraft repair	Traditional/Home remedies (eg, azarcon, kohl, ayurvedic)
X-ray shielding/Film radiology	Imported candy and candy wrappers
Hobbies and related activities	Supplements (eg, calcium)
Home remodeling/renovation	
Car or boat repair	
Glazing/Making pottery	
Reloading/Target shooting at firing ranges	
Furniture refinishing	
Making/Handling lead shot and fishing weights/sinkers	
Using lead soldering/welding	
Oil painting (artistic)	
Using pastel art pencils	
Making stained glass	
Jewelry making	
Using/Making diving and exercise weights	
Repairing old painted wooden or metal toys	

Note: Lead-based paint and lead contaminated dust are the most common sources of lead exposure for children.

of a year this measure can also be a sign of longer-term exposure.[16]

Workers are also at particular risk in battery manufacturing, demolition work, welding, pottery and ceramic-ware production (often a home-based occupation involving women and children), small businesses repairing automobile radiators, and artisan production of jewelry and decorative items. The last category is of particular concern since the work is predominantly carried out at home or in unregulated workshops, often by women and children. Although adults are mainly

involved, in many countries (especially those with developing industries), particularly in small home-based enterprises, there is little distinction between home and workplace, and children are consequently exposed to lead. Because of the transfer of lead to the fetus in utero and the introduction of lead into people's homes on clothing, through which young children are exposed, problems of occupational exposure become community problems.[7,17]

Because of rapid industrialization and the persistence of lead in the environment, exposure is likely to remain a significant public health problem in most developing countries for many years; this includes in Al-Madinah, Saudi Arabia. To prepare an action plan, one must first know the prevalence of lead exposure and its sources among the population most affected; namely, children.

The current study was conducted to estimate the prevalence of blood lead levels (BLLs) and to identify the sources of environmental exposure and potential risk factors for elevated BLLs among Saudi schoolchildren.

Subjects and methods

A cross-sectional survey was conducted from March to May 2010. The study population included Saudi school students (of elementary, intermediate, and secondary schools) of both sexes. The total number of students to be selected was estimated using the following formula: $n = (Z^2 \times P \times q)/D^2$.[18] Since the actual prevalence of elevated BLL is 20%, the probability of its occurrence was estimated to be $P = 0.20$. Accordingly, the probability of nonoccurrence will be $q = (1 - P) = 0.80$. A value of 0.03 was chosen as the acceptable limit of precision (D) at 95% confidence intervals (CIs) where ($Z = 1.96$). Based on these assumptions, the sample size was estimated at 682.95 children. For ease of calculation and analysis, 685 was chosen as the minimum sample size. The proposal was approved by the human subjects committees at the Taibah University, Ministry of Health, and Ministry of Education, Kingdom of Saudi Arabia.

A multistage sampling technique was used. First, a review of the records of all schools (elementary, intermediate, and secondary schools for boys and girls) was undertaken, and the schools were listed by grade and sex. Then, one school from each grade and each sex was randomly selected. After allocation of the selected schools, classes were enlisted, and then students were simply selected randomly.

Questionnaire

An anonymous self-administered questionnaire was distributed to the students at their schools to take home for their parents to fill in. The questionnaire was prepared in Arabic. Some questionnaires had to be administered by trained interviewers because some parents were not able to complete them without assistance. The purpose, procedure, risks, and benefits of the study were explained to the respondents and verbal and written informed consent was obtained. The survey tool was pre-tested on a random sample of 20 participants to ensure practicability, validity, and interpretation of responses. The reliability of the questionnaire was assessed using Cronbach's alpha (0.812). The questionnaire included queries on family size; socioeconomic status, including questions on number of possessions, house condition (year of construction, presence of lead pipes, last time the house was painted, number of rooms and bedrooms in the house, whether the family owned or rented the house), parents' education, and employment status; characteristics of school construction; pregnancy outcomes (birth weight and gestational age); breastfeeding history (duration of breastfeeding and child's age at the time liquids other than breast milk and solid foods were introduced); and the child's health (history of anemia, use of iron-fortified formula or cereals, whether the child uses a pacifier or puts fingers/toys in his/her mouth) and general diet (how many times in the last week did the child consume any fruits, vegetables, meat, eggs, legumes, and dairy products). The "family possessions" variable was constructed by summing the presence in the household of one or more of the following items: TV, video player, DVD player, computer, video games, radio, sound equipment, refrigerator, washer, house phone, cellular phone, or car.

BLLs were analyzed by Zeeman background-corrected flameless graphite furnace atomic absorption (model Z-8100; Hitachi, Tokyo, Japan). The limit of detection for the blood lead concentrations was 1.0 µg/dL.[19] Hemoglobin was assessed by a Sysmex XE-2100 Automated Hematology Analyzer (Sysmex, Kobe, Japan) with the appropriate calibrator, reagent kits, and quality control processes.[20]

The mean percent score was calculated (using the formula: total score/maximum possible score $\times$ 100) for the following: household exposure (household construction characteristics; see next paragraph), school exposure (school construction characteristics; see below), family, personal, and eating habits.

Hierarchical cluster analysis was used to summate the following: housing construction characteristics (including presence of a workshop or factory near house, width of street, type of house, paint, ground type, water source, and presence of water tanks), school construction characteristics

**Table 2** Demographics of the students in the blood lead level (BLL) survey by school grade, sex, age, and BLL

Parameters	School level						Total	
	Elementary[a]		Intermediate[b]		Secondary[c]			
	N = 204	%	N = 188	%	N = 165	%	N = 557	%
Sex								
Males	109	53.4	102	54.3	85	51.5	296	53.0
Females	95	46.6	86	45.7	80	48.5	261	47.0
Age in years								
6 < 12	204	100.0	–	–	–	–	204	36.6
12 < 15	–	–	188	100.0	–	–	188	33.7
15 < 18	–	–	–	–	165	100.0	165	29.6
BLL (μ/dL)								
<1 μ/dL	39	19.1	38	20.2	28	17.0	105	18.9
1 < 2.5 μ/dL	28	13.7	30	16.0	32	19.4	90	16.2
2.5 < 5 μ/dL	25	12.3	26	13.8	30	18.2	81	14.5
5 < 7.5 μ/dL	47	23.0	40	21.3	23	13.9	110	19.7
7.5 < 10 μ/dL	56	27.5	43	22.9	41	24.8	140	25.1
≥10 μ/dL	9	4.4	11	5.8	11	6.7	31	5.6

Notes: Values are expressed as means ± standard deviation or percentage scores. The sample size of each school level was calculated according to the number of students in each school grade level. [a]Elementary: school grade levels from grade 1 to grade 6. [b]Intermediate: school grade levels from grade 7 to grade 9. [c]Secondary: school grade levels from grade 10 to grade 12.
Abbreviation: BLL, blood lead level.

(including presence of workshop or factory near school, width of street, paint, floor, and ground type), family habits (including bakhoor [from the Arabic language; used to describe most incense resins or fragranced wood chips] use, smoking, utensils used in food storage and preparation), personal (use of kohl [an ancient eye cosmetic], cosmetics, lip gloss in females, playing with newspapers, putting colored toys in mouth; and up to the end of elementary school, using colored pencils), and eating habits (including canned food; canned juice; type of utensils used for food preparation and storage; use of newspapers in food preparation, storage, wrapping, and as table mats). After cluster analysis, correlation of some parameters with BLL <10 μg/dL and BLL >10 μg/dL was undertaken.
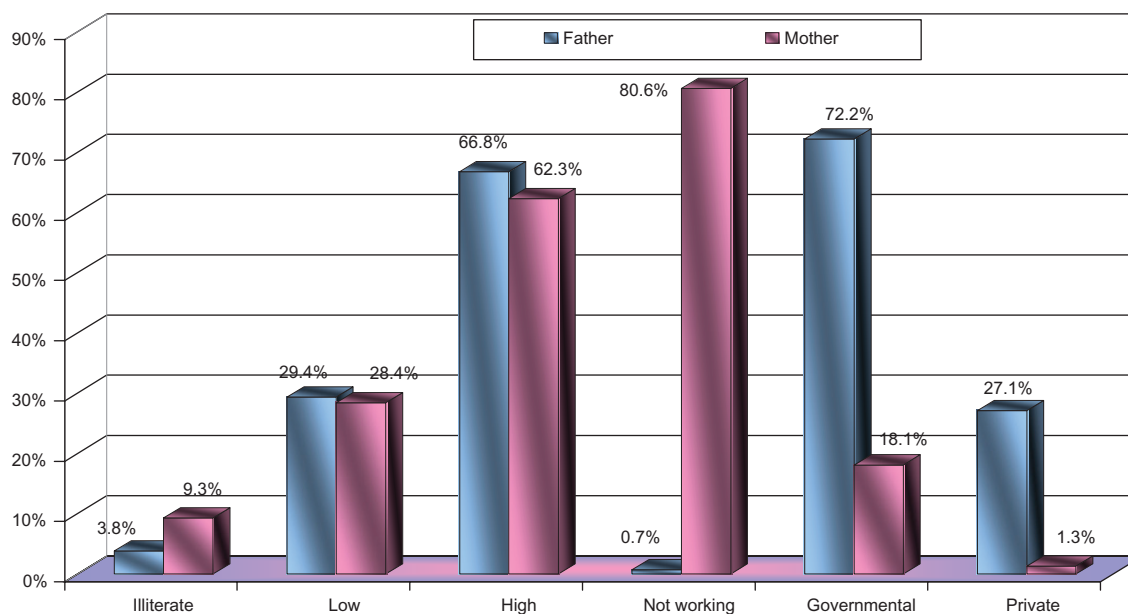
Figure 1 Education and work status of father and mother.
Notes: Values are expressed as means ± standard deviation or percentage scores. Odds ratios with 95% CI are reported for all variables entered into multivariate analysis (*P* < 0.05).

Statistical analysis

Data were entered and analyzed using SPSS (v 13.0; IBM Corp, Armonk, NY). Data gathered from the cross sectional survey were analyzed using the case control approach. The chi-square test was used for comparisons of nonparametric data. Student's *t*-test was used for comparisons of parametric data. Spearman's rank correlation was used to study correlations. Odds ratio (OR) and the corresponding 95% CI were computed for high BLL. Multiple linear regressions were performed to predict possible causes for increase in BLL.

Table 3 Association between blood lead level and family and personal habits

	<10 μg/dL, n = 533		≥10 μg/dL, n = 24		OR*	CI at 95%
	N	**%**	**N**	**%**		
Use of bakhoor[a]						
No	100	18.8	1	4.2	5.3	5.0–6.1
Yes	433	81.2	23	95.8		
Passive smoking						
No	313	58.7	9	37.5	2.4	1.2–5.5
Yes	220	41.3	15	62.5		
Putting colored toys in the mouth						
No	313	58.7	2	8.3	15.7	3.6–16.2
Yes	220	41.3	22	91.7		
Using colored pencils						
No	117	22.0	1	4.2	6.5	4.8–8.7
Yes	416	78.0	23	95.8		
Some food habits						
Eating canned food						
No	159	29.8	1	4.2	9.8	7.0–10.1
Yes	374	70.2	23	95.8		
Drinking canned juice						
No	88	16.5	2	8.4	2.2	1.4–3.8
Yes	445	83.5	22	91.6		
For females only (n = 262)						
Cosmetic use						
No	127	52.0	1	5.6	18.5	14.4–19.8
Yes	117	48.0	17	94.4		
Use of kohl[b]						
No	64	26.2	1	5.6	6.0	5.7–8.3
Yes	180	73.8	17	94.4		
Use of lip gloss						
No	68	27.9	1	5.6		
Yes	176	72.1	17	94.4	6.6	6.1–7.4
Use of toothpaste						
No	121	22.7	1	4.2	6.8	5.8–7.8
Yes	412	77.3	23	95.8		
Use of newspapers in:						
Playing						
No	473	88.7	21	87.5	1.1	1.1–3.9
Yes	60	11.3	3	12.5		
During food preparation						
No	356	66.8	5	20.8	7.6	6.3–8.2
Yes	177	33.2	19	79.2		
Wrapping and preserving food						
No	416	78.0	10	41.7	5.0	2.2–3.5
Yes	117	22.0	14	58.3		
As table mats						
No	333	62.5	5	20.8	6.3	5.2–7.6
Yes	200	37.5	19	79.2		

Notes: Values are expressed as means ± standard deviation or percentage scores. [a]"Bakhoor," from the Arabic language, is today used to describe most incense resins or fragranced wood chips. [b]Kohl is an ancient eye cosmetic. *Odds ratios (OR] with 95% confidence interval (CI) are reported for all variables entered into multivariate analysis (*P* < 0.05).

Results

A total of 557 students participated in the survey, corresponding to approximately 81.3% of the total number of students (685) eligible to participate from the 18 schools. Sex and age distributions varied considerably across schools because nine girls' schools constituted 47% of the recruited students with a mean age 11.6 ± 2.63 years, and nine boys' schools constituted 53% of the recruited students with a mean age 12.5 ± 3.5 years (Table 2). The mean BLL was 4.94 ± 3.38 µg/dL, with a significant difference between male and female BLLs (r = 0.406, P = 0.000). The distributions of BLLs across six blood-lead categories are presented in Table 2. In the three school study levels (elementary, intermediate, and secondary), 19% of children had BLLs <1.0 µg/dL, 16.2% had BLLs from 1.0 to 2.499 µg/dL, 14.5% had BLLs from 2.5 to 4.99 µg/dL, 19.7% had BLLs from 5.0 to 7.49 µg/dL, 25% had BLLs from 7.5 to 9.99 µg/dL, and about 5.6% had BLLs of ≥10 µg/dL (Table 2).

Geometric mean BLLs were significantly associated with family size and education level of the parent guardian. Figure 1 shows that 66.8% of fathers and 62.3% of mothers had a high level of education; meanwhile 80.6% of mothers were housewives. None of the fathers of the students who had BLLs of ≥10 µg/dL had occupational exposure to lead. The mean family size was 7.4 ± 2.12 and mean general crowding index was 1.6 ± 0.59. There was a significant relationship between mean family size and, general crowding index and BLL (r = 0.086, P = 0.042 and r = 0.112, P = 0.008, respectively).

Table 3 compares the general data of the surveyed individuals grouped according to BLLs. Study groups had significantly differentiated family and personal habits. Table 3 shows the association between BLLs and family and personal habits, where the highest risk values were associated with the use of cosmetics (OR = 18.5, CI = 14.4–19.8), putting colored toys in mouth (OR = 15.7, CI = 3.6–16.2), eating canned food (OR = 9.8, CI = 7.0–10.1), and using newspaper during food preparation (OR = 7.6, CI = 6.3–8.2). Using cluster analysis, Table 4 illustrates a significant correlation between BLLs and

family habits (r = 0.225, P = 0.000), personal habits (r = 0.321, P = 0.000), eating habits (r = 0.128, P = 0.002) and school construction characteristics (r = 0.469, P = 0.000).

There was a significant relationship between BLLs and family habits (P = 0.000, OR = 8.6, CI = 4.1–11.3), personal habits (P = 0.000, OR = 5.2, CI = 2.1–8.6), eating habits (P = 0.000, OR = 22.3, CI = 20.4–26.7), and mean percent score of possible sources of lead exposure (P = 0.000, OR = 35.5, CI = 34.1–40.5) (Table 5, Figure 2).

Regarding the relationship between BLLs and hemoglobin level, Table 6 shows that there was significant correlation in age group 6–11 years (P = 0.000) and age group 12–18 years, among males (P = 0.000) and females (P = 0.041).

It was found that the predictors for high BLL (Table 7) were the use of toothpaste (P = 0.000), kohl (P = 0.000), putting colored toys in the mouth (P = 0.000), canned food and canned juice (P = 0.008 and 0.018, respectively), use of lip gloss in females (P = 0.000), and different ways of handling newspapers while preparing food.

Discussion

Both occupational and environmental exposures to lead remain a serious problem in many developing and industrializing countries, as well as in some developed countries.[1] Lead is a potent poison that can affect individuals at any age. Children with developing bodies are especially vulnerable because their rapidly developing nervous systems are particularly sensitive to the effects of lead.[1,10] Lower age as a risk factor for elevated BLLs among children aged 6–18 years has not been investigated in many countries. The data presented in Table 2 show an apparent increase in BLLs in the young compared with older people. However, these results are inconsistent with reports from the USA and Australia, where BLLs are highest in 1- to 2-year-old children and decline later.[21] In contrast, a study from Russia reported little variation in lead levels by age.[22]

In the year 2000, an estimated 120 million people around the world had blood lead concentrations of between 5 and

Table 4 Correlation between blood lead level and some studied characters (cluster analysis)

Parameters	< 10µg/dL		≥ 10µg/dL		All studied groups	
	R[a]	Significance	R[a]	Significance	R[a]	Significance
Housing construction characteristics	0.023	0.603	0.024	0.580	0.046	0.282
Family habits	0.278**	0.000	0.051	0.811	0.255**	0.000
Personal habits	0.208**	0.000	0.060	0.781	0.321**	0.000
Eating habits	0.078	0.073	0.248	0.243	0.128**	0.002
School building characteristics	0.016	0.704	0.093	0.664	0.469**	0.000

Notes: [a]Spearman's correlation was used; **correlation is significant at 0.01 (two tailed).

Table 5 Mean percent score of possible sources of lead exposure

	<10 µg/dL	≥10 µg/dL	P value[a]
Household exposure	51.36 ± 12.67	54.69 ± 12.67	0.205
School exposure	66.94 ± 6.60	65.83 ± 6.53	0.420
Family habits	43.04 ± 19.09	75.83 ± 22.06	0.000*
Personal habits	55.56 ± 17.74	78.70 ± 10.32	0.000*
Eating habits	30.89 ± 21.35	72.22 ± 30.56	0.000*
Total exposure score	49.56 ± 8.78	69.46 ± 8.69	0.000*

Notes: [a]P for t-test; *P value significant below 0.05.

10 µg/dL, and about the same number had concentrations of >10 µg/dL. Forty percent of all children had blood lead concentrations of >5 µg/dL and half of these children had blood lead concentrations of >10 µg/dL; of these children, 97% were living in developing countries. The present work showed that 4.3% of students aged 6–18 years had BLLs > 10 µg/dL, with a mean of 4.94 ± 3.38 µg/dL. This finding was less than expected and even approaches that of developed countries, indicating decreased exposure to different lead sources. Most of the parents and teachers from each school had a high degree of general hygiene – both at home and at school – despite the fact that they were unaware of the risks of lead poisoning and the possible degree of exposure to lead.[2]

According to the Centers for Disease Control and Prevention (CDC 1991),[13] the definition of an elevated concentration of lead in the blood is 10 µg/dL. However, evidence indicating that some health effects can occur below this threshold is accumulating. Recent analyses suggest that health effects may become apparent at concentrations of <5 µg/dL and, indeed, that no evidence exists for a threshold, even at 1 µg/dL.[14]

Blood lead concentration is an indicator of recent lead exposure (within the preceding few weeks), rather than of cumulative long-term exposure. However, as exposure to lead

varies relatively little over the span of 1 year,[23] this measure can also be used to assess long-term exposure.[22] This was consistent with this research finding where school construction characteristics, family ($P < 0.0001$), and personal and eating habits ($P < 0.0001$) were correlated with BLL.

A few studies reported small differences (typically <10%) between blood lead concentrations in males and females.[23] This finding was true for this study, where there was a significant difference between males' and females' mean BLLs. Males were associated with elevated BLL, which may be due to behavioral differences between boys and girls. In the Second and Third National Health and Nutrition Examination Surveys, the prevalence of elevated BLL was higher among boys than in girls, but the difference was not statistically significant.[24,25]

Much research has been conducted recently on children with moderately raised BLLs associated with environmental exposure. The potential for adverse effects of lead exposure in children is heightened because: the intake of lead per unit body weight is higher for children than for adults; young children often place objects in their mouths, resulting in the possibility of dust and soil contaminated with lead being ingested; physiological uptake rates of lead in children are higher than those in adults; young children are undergoing rapid development; and their systems are not fully developed.[26,27] Unlike overt lead toxicity, where there is usually one identifiable source, low-level environmental exposure to lead is associated with multiple sources (petrol, industrial processes, paint, solder in canned foods, water pipes) and pathways (air, household dust, street dirt, soil, water, food).[17,28] In the current study, it was found that the possible sources for lead may be use of toothpaste, use of kohl, putting colored toys in the mouth, use of both canned food and juice, use of lip gloss in females, and different methods of handling newspaper while preparing
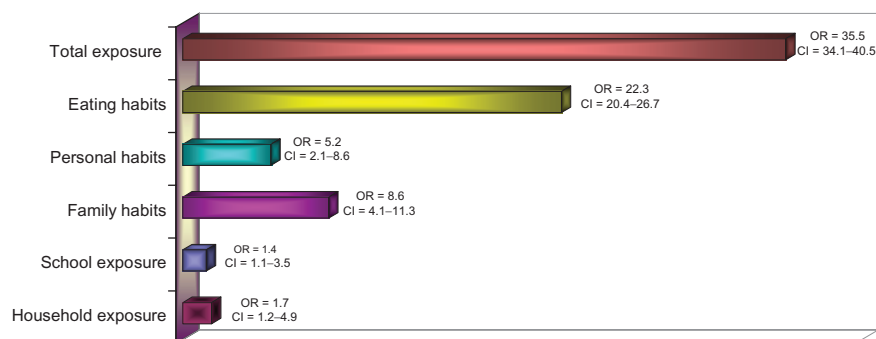
Figure 2 Association between BLL and scores of possible lead exposure (odds ratios [OR]).
Notes: Values are expressed as means ± standard deviation or percentage scores. Odds ratios with 95% confidence intervals (CI) are reported for all variables entered into multivariate analysis ($P < 0.05$).

Table 6 Relationship between blood lead level and hemoglobin level by age group

	<10 µg/dL, mean ± SD	≥10 µg/dL, mean ± SD	*P* value
6 ≤ 12 years (both sexes)			
All group (N = 235)	12.40 ± 1.17	9.33 ± 0.94	0.000*
Non-anemic group (N = 204)	12.77 ± 0.58	10.66 ± 0.68	0.000*
[a]Anemic group (N = 31)	10.09 ± 1.28	8.87 ± 0.75	0.000*
12 ≤ 18 years			
Males			
All group (N = 172)	13.45 ± 0.90	10.55 ± 1.27	0.000*
Non-anemic group (N = 129)	13.85 ± 0.49	–**	–
[b]Anemic group (N = 43)	12.13 ± 0.67	9.00 ± 0.00***	0.000*
Females			
All group (N = 150)	12.31 ± 1.11	10.42 ± 1.26	0.000*
Non-anemic group (N = 103)	12.86 ± 0.61	12.0 ± 0.00***	0.165
[c]Anemic group (N = 47)	10.26 ± 1.21	10.89 ± 0.74	0.041*

Notes: *P value for *t*-test significant below 0.05; **number = 0; ***number = 1; [a]normal range for this age: 11.5–13.5 mg/dL; [b]normal range for age and sex (male): 13–14.5 mg/dL; [c]normal range for age and sex (females): 12–14 mg/dL.

food – nearly the same sources found by other research as stated above.

This work indicated a significant relationship between BLL and hemoglobin level, especially among females ($P < 0.0001$) with lower mean hemoglobin level than males, and especially for age group 12–18 years. Hazards for anemia and gastrointestinal effects were based on a large review of toxicological and epidemiological data.[27] Based on the results of a study by Schwartz, et al,[29] as a consequence of individual variation, we considered that only 20% of the people with blood lead concentrations above those indicated by the Agency for Toxic Substances and Disease Registry would actually develop symptoms.[29,30] Absorbed lead inhibits the activity of a number of enzymes involved in heme biosynthesis. Several studies have shown that the activity of δ-aminolevulinic acid dehydratase is affected at very low BLLs, with no apparent threshold.[31] Typically, lead-induced

anemia arises from a combination of reduced hemoglobin formation (caused either by impaired heme synthesis or globin chain formation) and reduction in erythrocyte survival because of hemolysis.[32]

Conclusion

Female students have a higher blood lead level than males. They also have a lower blood hemoglobin level. The possible sources of lead exposure included the use of toothpaste, kohl, canned food and canned juice, putting colored toys in the mouth, use of lip gloss in females, and different methods of handling newspaper while preparing food.

Recommendation

A health-education intervention program should be planned and directed to parents, teachers, and students to increase their awareness of sources of lead exposure and how to avoid

Table 7 Predictors of high blood lead level among schoolchildren

	B	β	t	Significance	95% of CI for B**
Use of bakhoor[a]	0.006	0.012	0.309	0.757	–0.034 to 0.046
Use of toothpaste	0.074	0.151	3.710	0.000*	0.035–0.113
Use of kohl[b]	0.080	0.194	4.671	0.000*	0.046–0.114
Passive smoking	0.027	0.065	1.693	0.091	–0.004 to 0.57
Putting colored toys in mouth	0.057	0.140	3.613	0.000*	0.026–0.088
Use of canned food	0.051	0.113	2.674	0.008*	0.014–0.088
Use of canned juice	0.056	0.101	2.366	0.018*	0.010–0.102
Use of cosmetics	0.019	0.039	0.720	0.472	0.071–0.033
Use of lip gloss	0.118	0.270	4.587	0.000*	0.067–0.168
Use of newspapers					
Food preparation	0.062	0.146	3.509	0.000*	0.027–0.097
Table mats	0.130	0.312	6.999	0.000*	0.093–0.166
Wrapping	0.960	0.200	4.940	0.000*	0.058–0.134
Use of colored pencils	0.027	0.054	1.400	0.162	–0.011–0.065

Notes: *Significance below level of 0.05; **Confidence interval (CI). [a]"Bakhoor," from the Arabic language, is today used to describe most incense resins or fragranced wood chips. [b]Kohl is an ancient eye cosmetic.

them. Possible interventions include providing soap and water at schools and homes, frequently washing hands and face, thoroughly cleaning fruits and vegetables, and limiting dust on floors and furniture. Children should be educated not to suck on their fingers, pencils, or toys, or to eat soil. A treatment plan should be designed for those who have an elevated BLL, with continuous evaluation.

Study limitation

An assessment of the effect of BLL upon scholastic achievement together with measurement of the intelligence quotient for both students and their parents (especially mother) were needed, but many difficulties (related to schools, students, and parents) faced the authors in carrying these out.

Acknowledgments

Disclosure

The authors report no conflicts of interest in this work.

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