Environmental Lead Exposure among Primary School Children in Shebin El-Kom District, Menoufiya Governorate, Egypt

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Abstract

Background: Lead still remains an important problem for poor, inner-city, ethnic minority children, with a particular emphasis on lead paint and dust. In Egypt, there is no national survey about the prevalence of elevated blood lead level among children.

Objective: To assess the environmental lead level as well as to determine blood lead level among primary school children and find out its relationship with their intelligent quotient (IQ), hemoglobin level, hearing impairment and school performance.

Methods: 190 primary school children from rural and urban areas were selected and their blood lead levels (BLL), hemoglobin concentrations, IQ, hearing threshold and school performance were measured. Also, environmental lead level was measured in the school and home.

Results: The mean value of environmental lead (µg/m^3) in urban schools air was significantly higher than that in rural areas. BLL had a significant negative correlation with hemoglobin level and IQ; it was positively correlated with the hearing threshold. With increasing BLL, the school performance of children decreased significantly.

Conclusion: Exposure to lead would deteriorate IQ, school performance and hearing level of school children. Even in the absence of overt clinical manifestations of lead toxicity, lead intoxication should be among differential diagnosis in children presenting anemia, intellectual impairment, poor academic performance and hearing impairment.

Keywords: Lead; Lead poisoning; Hearing loss; Intelligence test; Anemia; Learning; Students

Introduction

Lead is a hazardous, heavy metal that has a destructive effect on human health. Evidence from many research studies conducted in various countries suggests that human exposure to lead is one of the most serious health problems facing people, especially children, although exposure to lead is a preventable risk.[1] In fact, lead remains an important problem for poor, inner-city,

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ethnic minority children, with a particular emphasis on lead paint and dust.[2]

Lead poisoning may take one of the two forms of acute and chronic poisoning. Manifestations of chronic lead poisoning depend on the age of the exposed person and the amount of lead accumulated in his body. Careful longitudinal cohort studies have shown that children with high lead exposure are at risk for developing a low intelligent quotient (IQ), disturbed balance, learning disabilities, behavioral problems, hearing impairment and growth retardation. Lead poisoning has been associated with a significant increase in high school dropout rate, and an increase in criminal behavior.[3]

The US Centers for Disease Control and Prevention (CDC) guidelines define elevated blood lead levels as a level ≥10 µg/dL for children.[4] However, evidence is now emerging that even levels less than 10 µg/dL can cause neurological damage.[5]

In Egypt, there is no national survey about the prevalence of elevated blood lead levels among children. This study was therefore conducted to assess the environmental lead level, to determine blood lead level (BLL) among primary school children, and to find out the relationship between BLL among studied children and their IQ, complete blood picture (CBC), hearing impairment and school performance.

Materials and Methods

This cross-sectional study was conducted in primary schools of Shebin El Kom district, Menoufiya governorate, Egypt. Shebin El Kom district has a population of 191 625 school students studying in 102 primary schools. From 26 schools in Shebin El Kom city, and 76 rural schools in Shebin El Kom district, "El Salam" and "Tanbedi" primary schools were chosen by simple random sampling to represent the urban and rural primary schools, respectively. From each school, three educational grades were chosen by systematic random sampling; they were the first, third, and the fifth grades. One class from each grade was then chosen by simple random sampling. Ninety children from each school were chosen to participate in this study; they were chosen equally from the three studied grades.

Participants were all volunteers. A permission letter from the Ethical Committee of the Faculty of Medicine, Menoufiya University, was taken before conduction of the study. Also, an official permission was obtained and directed to the undersecretary of the studied schools. A written consent form was signed by each child's respondent shared in the study after explaining the study objectives.

Each participant's parent or responsible person was asked to complete a predesigned questionnaire including socio-demographic data, house and school environment, housing conditions, painting age, frequency of house cleaning and other related habits of the child and recent scholastic achievements. The traffic density of the school areas was considered "low" in Tanbedi school (average 7 cars/hr), and "high" in El-Salam school (average 102 cars/hr). Houses constructed ≥50 years, were considered "old" while those aged <50 years, were considered "recent." According to the painting age, painting was considered "old" if it is ≥25 years and "recent" if it is <25 years old.

The IQ of each student was assessed by Arabic version of Wechsler scale, validated by Meileka, 1983.[6] The hearing of each student was assessed for both ears by diagnostic audiometer AS 67 (Danplex). A CBC was also done for each child. BLL was measured by atomic-absorption spectrophotometry using an extraction procedure;[7] 0.5 mL of blood sample was transferred into a digester glass tube of

For more information on the history of lead poisoning see www.theijoem.com/ijoem/index.php/ijoem/article/view/28/61

> **TAKE-HOME MESSAGE**
>
> - Heavy metals have destructive effects on human health, especially in children.
> - Lead poisoning may take one of the two forms of acute and chronic poisoning. Manifestations of chronic lead poisoning depend on the age of the exposed person and the amount of lead accumulated in his body.
> - Children with long-term exposure to lead are at risk of developing a low intelligence quotient, disturbed balance, learning disabilities, behavioral problems, hearing impairment and growth retardation.
> - Lead-free gasoline, cleaning up of lead contaminating sources from the industrial areas, and using natural gas in power generation sectors would result in significant decrease in atmospheric lead concentration.
> - Lead intoxication should not be ignored as a differential diagnosis in cases of anemia, intellectual impairment, poor academic performance and hearing impairment even in those without any overt clinical manifestations of lead poisoning.

Kjeldahl digestion unit; 6 mL tri-acids mixture (containing nitric acid, perchloric acid and sulfuric acid in the ratio of 20:4:1 v/v, respectively) were added to each tube. The tubes contents were digested gradually as follows: 30 min at 70 °C, 30 min at 180 °C, and 30 min at 220 °C. After digestion, the mixture was cooled, dissolved in distilled water and the volume was increased to 50 mL in volumetric beaker. After filtration in ashless filter paper, aliquots were analyzed for lead.

Some samples collected from the surrounding environment of the schools were also analyzed for lead level. The samples included three air samples from each school, three soil samples from the playground of each school, one dust sample on windows from each class in each school, five urban and five rural samples from the dust on each of windows of children's houses and home carpets. We also used five expensive and five cheap toys for the purpose of analysis. Expensive and cheap toy were defined based on their trade mark as well as their prices.

Using a noise level meter the environmental noise level (in dB) was measured at three points in each of the studied classes. Environmental and blood lead level were measured in National Research Institute Laboratory, Dokky, Cairo, Egypt.

Statistical analysis

Data were analyzed by SPSS® for Windows® ver 20.0. Quantitative data were expressed as mean and standard deviation. Kolmogorov-Smirnov test was used to test the normality of the data distribution. *Student's t* test was used for comparison of means between two groups of normally distributed variables; Mann-Whitney U test was used for comparison of two groups of non-normally distributed variables. Kruskal Wallis test was used for comparison of three or more groups of non-normally distributed variables. Qualitative data were expressed as number and percentage and were analyzed by χ^2 test. Pearson correlation coefficient was used to assess association between quantitative variables. A $p<0.05$ was considered statistically significant.

Results

The mean environmental lead level in the urban school air was significantly higher than that in rural one (Table 1). Also,

Table 1: Mean concentration of environmental lead in the investigated sites

Environmental lead	Number of samples in each place	Mean±SD		p value
		Rural area	Urban area	
In school air (µg/m³)	3	0.14±0.011	0.21±0.011	<0.001
In playground school soil (ppm)	3	80.0±3.03	80.67±1.53	0.75
In school window dust (ppm)	3	78.33±2.08	79.0±2.64	0.75
In house window dust (ppm)	5	78.50±3.83	80.70±4.08	0.40
In home carpet dust (ppm)	5	76.9±3.69	79.0±5.07	0.48

the mean±SD lead level in cheap toys (370±5.28 ppm) was significantly higher than that in expensive ones (122.0±2.28 ppm). The mean±SD BLL in the studied students was 6.72±4.3 µg/dL; 25.6% of studied children had a BLL ≥10 µg/dL.

The mean±SD environmental noise level measured at the studied classes of urban school (55.0±17.14 dB) was not significantly (p=0.11) different from that of the rural school (42.56±12.71). BLL of the student I rural schools was not significantly different from those in urban schools. No significant difference was observed between children with elevated BLL and low BLL in terms of socio-demographic data, housing conditions (house age, painting age and painting state) and home environment (type of floor, place of sleep, presence of carpets, rate of cleaning and source of water). Living in a house or going to a school near high traffic density area and paved roads was significantly associated with a higher BLL in studied students (Table 2). The mean±SD BLL in children with delayed school performance

Table 2: Relationship between blood lead level and house and school environment among studied children

House and school environment	n	Mean±SD BLL (µg/dL)	p value
Traffic density around house			
High	86	6.0±4.16	0.004
Low	94	5.41±4.45	
Traffic density around school			
High	90	6.22±3.9	0.02
Low	90	4.4±4.74	
Paved road			
Yes	94	6.22±4.32	0.01
No	86	5.17±4.25	
Street width			
< 6 meters	150	5.43±4.2	0.07
≥ 6 meters	30	7.16±4.58	

Table 3: Relationship between blood lead level and IQ, hearing and Hb levels among studied group

Parameter	Mean±SD		p value
	BLL<10 μg/dL (n=134)	BLL≥10 μg/dL (n=46)	
IQ	94.72±5.99	88.8±13.49	<0.001
Hearing threshold (dB)	15.63±7.89	18.8±9.42	0.03
Hb (g/dL)	12.63±1.02	12.11±1.12	0.004

(7.0±4.17 μg/dL) was significantly higher than that in those with good school performance (5.23±4.3 μg/dL). The mean IQ and hemoglobin level was significantly lower in students with BLL ≥10 μg/dL than those with BLL <10 μg/dL; BLL was also associated with hearing threshold (Table 3). The prevalence of putting hands and toys in mouth, eating canned food and preserve food in newspaper was significantly higher among children with high BLL than those with low BLL; the percentage of washing hands before eating and weekly toy cleaning was significantly lower among the former group than the latter one (Table 4). There was a significant negative correlation between BLL and both hemoglobin level and IQ (r=0.196, and 0.217, respectively; p=0.03), where there was a significant positive correlation between BLL and hearing threshold (r=0.167, p=0.04).

Discussion

The mean±SD blood lead level of the studied students was 6.72±4.3 μg/dL; 25.6% of them had a BLL ≥10 μg/dL. This finding is in keeping with another Egyptian study reporting that the mean±SD BLL among children in Cairo was 4.82±2.97 (range: 1.1–14.3) μg/dL.[8] Another Egyptian study reported a mean±SD BLL of 8.8±1.5 μg/dL in children living in a non-industrial area.[9] A study done in Mexico reported that the BLL of children whose fathers worked in home-based workshops (22.4 μg/dL) was significantly higher than those whose fathers worked in an external workshops (14.2 μg/dL); BLL in children whose fathers were not occupationally exposed to lead was significantly lower (5.6 μg/dL).[10] In the USA, the mean BLL in children had decreased from 2.7 to 2.1 μg/dL since the late 1970's.[11]

In the current study, the lead concentration in the school ambient air of the urban area was 0.21 μg/m^3; in the rural area, it was 0.14 μg/m^3. Both of these val-

Table 4: Frequency of various habits among studied children stratified by their blood lead level

Parameter	n (%)		p value
	BLL <10 μg/dL (n=134)	BLL ≥10 μg/dL (n=46)	
Putting hands in mouth	25 (18.7)	16 (35)	0.02
Putting toys in mouth	31 (23.1)	21 (46)	0.003
Washing hands before eating	96 (71.6)	22 (48)	0.003
Weekly toy cleaning	86 (64.2)	20 (44)	0.01
Eating canned food	36 (26.9)	21 (46)	0.01
Preserve food in newspaper	39 (29.1)	22 (48)	0.02

ues were below the maximum Egyptian limit defined in the executive regulation of the law number 4/1994 as being 1 µg/m³. The environmental protection agency (EPA), however, has taken significant steps to protect the health of children by lowering the threshold for lead in the ambient air to 0.15 µg/m³ which is a tenfold reduction from the previous standard of 1.5 µg/m³ which dates back to 1978.[12]

Some authors reported a significant decrease in atmospheric lead concentration from 1999 to 2002 from a mean±SD value of 1.19±0.81 to 1.08±0.09 µg/dL, respectively.[8] They explained this significant decrease by the efforts made to improve air quality especially lead emissions. These efforts included introduction of lead-free gasoline, cleaning up of lead contaminating sources from the industrial areas by their relocation outside the residential blocks, as well as switching to the natural gas instead of Mazout in the industrial areas and power generation sectors. In 1996, unleaded gasoline was only sold in Cairo gasoline stations;[13] the leaded gasoline is still in use in other Egyptian governorates.

We found that cheap toys contain a significantly higher lead content than expensive toys. Lead can be found in products such as kohl—a South Asian cosmetic—and in some toys.[14] In the year 2007, millions of toys made in China were recalled from multiple countries owing to safety hazards including lead paint.[15]

We showed that living in a house or going to a school near high traffic density area and paved roads was significantly associated with a higher BLL in studied students. In a study on 60 Egyptian children aged 6–12 years, the mean BLL of those who lived in Alexandria city—an urban area—was significantly higher than that of those who lived in Kafr Al-Sheikh—a rural area; 56.7%, and 6.7% of children from Alexandria and Kafr El-Sheikh, respectively, had a BLL more than 20 µg/dL.[16] On the other hand, a study conducted in 164 Egyptian children found that the mean BLL was 12.96 µg/dL. Forty-six percent of rural children had BLL >15 µg/dL, whereas only 20% of urban children had levels >15 µg/dL. The finding that children lived in high traffic areas had a significantly lower BLL than those who lived in low traffic regions was unexpected. However, children living in low traffic areas are more likely to spend most of their time playing in the streets, where are quiet and safe; they are thus more exposed to the lead in the dust and soil in the contaminated outdoor environment that would result in a higher BLL in these children. In addition, low traffic streets are more likely to be narrow and unpaved or unmaintained, leading to increased possibility of lead exposure.[17]

We observed no significant relationship between the mean BLL and age of the house, and painting age and status. This finding is in agreement with another study.[18]

We found that children with BLL ≥10 µg/dL put their hands or toys in their mouth, ate canned food, and preserved food in newspapers more often than children with BLL <10 µg/dL; they also washed their hands before eating and cleansed their toys less frequently than the latter children. It was reported that history of wrapping sandwiches in newspapers and putting hand in mouth was a significant predictor of lead exposure.[15] Food and Drug Administration (FDA) has set an action level of 0.5 µg/mL for lead in products intended for use by infants and children and has banned the use of lead-soldered food cans.[19]

In this study, the mean BLL of students with delayed school performance was significantly higher than that in those with good school performance. Exposure to lead in early childhood would negatively affect the Connecticut Mastery Test (CMT) scores in both reading and mathematics.[20] Also, it was found that reduced academic performance is associated with lead exposure even at BLLs lower than 5 μg/dL.[21]

We also showed that students with BLL ≥10 μg/dL had a significant lower IQ than those with BLL <10 μg/dL—there was a significant negative correlation between BLL and IQ. This is in keeping with another report that showed that a higher BLL was associated with significant decline in the IQ full scale.[22] Lead exposure in young children has been linked to lower IQ and learning disabilities.[10,23] Moreover, a significant correlation between BLL and decreased intelligence, non-verbal reasoning, short-term memory, attention, reading and arithmetic ability and fine motor skills was reported.[24] It was found that children's intellectual function at the age of six is impaired by BLLs well below 10 μg/dL.[25] Accumulating evidence since 1991 suggests that children's intellectual ability is adversely affected at BLLs <10 μg/dL.[26,27] A five-year study on 172 children found that lead causes intellectual impairment even at low levels; the IQ score for children with BLL of 10 μg/dL was 7.4 points lower than that for children with a BLL of at 1 μg/dL.[28] Lead's subtle health impacts from exposure to lead at blood levels of 10 μg/dL include increased attention-related behavioral problems, lower performance in school and lower IQ.[29,30] Collectively, many new studies and re-interpretation of past studies have demonstrated that it is not possible to determine a threshold below which BLL is not inversely related to IQ.[31]

We found that students with BLL ≥10 μg/dL had a significant higher hearing threshold than those with BLL <10 μg/dL; there was a significant positive correlation between BLL and hearing threshold. Another study also revealed that lead was associated with an increased risk of hearing thresholds that were elevated above the standard reference level; even low level of exposure has been associated with devastating effect on hearing thresholds in children.[32]

Our study revealed that the mean hemoglobin level in students with BLL ≥10 μg/dL was significantly lower than that in those with BLL <10 μg/dL. This finding is in accordance with another report.[18] Lead interferes with enzymes ferrocatalase and delta-aminolevulinic acid dehydratase, which are important in the heme biosynthesis.[33,34]

Based on the findings of this study, it seems that a wide survey including primary school children at different governorates of Egypt should be done to assess the problem of lead intoxication in more detail. Periodic screening of children is mandatory to re-evaluate the efficiency of protective measures undertaken. Lead intoxication should not be ignored as a differential diagnosis in cases of anemia, intellectual impairment, poor academic performance and hearing impairment even in those without any overt clinical manifestations of lead poisoning.

Conflicts of Interest: None declared.

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