Lead screening in children presenting to three hospitals in Lebanon

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ABSTRACT

Background Lead damages most body organs and its effects are most profound in children. In a study in Beirut in 2003, before banning the leaded gasoline, 79% of the participants showed blood lead levels (BLLs) higher than 5 µg/dL. The prevalence of lead exposure in Lebanon after the ban on leaded gasoline has not been studied. This study assessed the BLL in Lebanese children aged 1–6 years.

Methods This cross-sectional study was conducted in three hospitals in Beirut. The children's BLLs were tested, and their caregiver completed a questionnaire to identify subgroups at risk of exposure. Participants were provided with a WHO brochure highlighting the risks of lead.

Results Ninety children with a mean age of 3.5±1.5 years were enrolled in the study and had a mean BLL of 1.1±0.7 µg/dL, with all values being below 5.0 µg/dL, showing a marked decrease in BLL compared with the mean BLL before the ban on leaded gasoline in 2002. Having a father or a mother with a college degree (p=0.01 and p=0.035, respectively) and having a monthly household income greater than $1000 (p=0.021) were associated with significantly lower BLL. Having more rooms at home and residing close to construction sites were associated with a significantly lower BLL (p=0.001 and p=0.026, respectively). Residing in a house aged >40 years and receiving traditional remedies were associated with a significantly higher BLL (p=0.009 and p<0.0001, respectively).

Conclusion BLLs have declined among Lebanese children and this could be attributed to multiple factors including the ban of leaded gasoline. It would be beneficial to conduct a larger study with a nationally representative sample to better characterise the BLL.

What is already known on this topic?

- Lead is toxic to humans and has major effects on neurodevelopment.
- The Centers for Disease Control and Prevention and WHO recognise that there is no safe blood lead level.
- Prior to the introduction of laws banning leaded gasoline in Lebanon, Lebanese children had elevated blood lead levels.

What this study adds?

- Blood lead levels in Lebanese children have declined since the introduction of the law banning leaded gasoline.
- Lebanese children are still exposed to lead in various extents.
- It is necessary to spread awareness about certain environmental and behavioural exposures such as the use of firearms and the practice of traditional medicine.

BACKGROUND

Lead is a metal that is used in multiple industries, and is an important environmental hazard contaminating water bodies and the atmosphere.[1] Lead enters the body through multiple routes and the acceptable blood lead level (BLL) has been constantly evolving. In 2012, the Centers for Disease Control and Prevention (CDC) moved away from the term 'threshold for acceptable BLL', and changed the reference level from 10 to 5 µg/dL.[2] Moreover, Public Health England in their 2019 report recommended to lower the interventional BLL level from 10 to 5 µg/dL.[3] The CDC, Public Health England and the WHO recognise that no BLL is safe.[1 3]

The impact of inorganic lead toxicity is being increasingly recognised worldwide as it can result in multiorgan damage[1] and is classified in category 2b (probably carcinogenic in humans) by the International Agency for Research on Cancer.[4] Lead exposure accounted for a million deaths in 2017, and over 24 million disability-adjusted life years, most of which occurred in low/middle-income developing countries.[1] The Institute for Health Metrics and Evaluation estimates that lead exposure is responsible for 12.4% of the international burden of idiopathic intellectual disability,[5] and it is negatively associated with neurodevelopment in young children.[2 6] Lead exposure can affect development by causing a reduction in IQ[7] score (with a steeper slope in BLLs under 10 µg/dL[8]) and attention span,[9 10] as well as an increase in antisocial behaviour, aggression and learning difficulties, which considerably impacts lives and nations.[8]

To address this matter, the second International Conference on Chemicals Management (Geneva, 11–15 May 2009) commended the United Nations Environment Program and the WHO on establishing the Global Alliance to Eliminate Lead Paint (GAELP).[11] According to the 2019 report on the progress of GAELP, 73 countries have legally

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binding limits on trading leaded paints, of which only 3 are in the Arab world. Although Lebanon is working on establishing similar regulations, there are currently no laws in place that address this matter.[12]

In 2003, Nuwayhid *et al*[13] showed that 14% of a sample of Lebanese children 1–3 years old had BLLs above 10 µg/dL. In 2001, the Lebanese parliament passed a law (law number 341/2002) prohibiting the use of lead-containing gasoline in Lebanon as of 1 January 2002.[14] Prior to that, approximately 90% of cars in Lebanon operated on leaded gasoline.[15] In their study, Nuwayhid *et al* recruited subjects between 1997 and 1998 when the law 341/2002 had not been enacted yet.

Given that the only screening study in Lebanon was performed more than 20 years ago, before the ban on leaded gasoline, there is a need to perform a follow-up study to determine the changes in lead levels by measuring the BLL in a sample of Lebanese children and identifying possible sources of exposure.

METHODS

Study setting

This cross-sectional study was conducted between August 2019 and March 2020 at the emergency departments and paediatric clinics of the American University of Beirut Medical Center (AUBMC), Saint George Hospital (SGH) and Bahman Hospital (BH), which are all located in Beirut, the capital of Lebanon. Children aged 1–6 years were recruited in order to assess their BLL. Written consent was obtained from the primary caregivers of the children before enrolling them in the study.

Outcome measures

Recruitment occurred by convenience sampling whereby a research fellow was present during different times of the day to enrol participants. After written consent was obtained from the primary caregivers, the questionnaire was delivered by the recruiter (online supplemental appendix A and online supplemental document S1).

After completing the questionnaire, the primary caregivers were counselled about lead toxicity and were provided with the WHO brochure on lead poisoning. Permission was obtained from the WHO to translate and reproduce the brochure, so the brochure was provided in both English and Arabic to better reach the Lebanese population (online supplemental appendix B).

For every participant, blood was drawn by a certified phlebotomist or nurse and placed in a metal-free EDTA tube. The samples were analysed at Bio Scientia Laboratories in Germany, which reported the BLL in *µ*g/dL. After the BLL was reported to AUBMC, the primary caregivers were informed of the results and necessary interventions.

Statistical analysis

Statistical analyses were performed using the SPSS (IBM SPSS V.25.0). Categorical variables were presented as frequency tables and continuous variables were presented as means and SDs. The participants were stratified according to the median BLL (0.9 µg/dL). The association between the stratified BLL and categorical variables was carried out using the X^2 and Fisher's exact tests. Student's t-test was used for the association with continuous variables. Multivariate analysis was performed to control for confounding variables. The results of the multivariate analysis were presented by the adjusted OR with a CI of 95%. A p value of <0.05 was considered statistically significant (online supplemental document S1).

Further details of the methodology can be found in the online supplemental material.

RESULTS

Demographics and socioeconomic status

Between August 2019 and March 2020, 90 participants were recruited in our study with 70.0% recruited at AUBMC, 22.2% at SGH and 7.8% at BH. The mean age was 3.5±1.5 years, and most were boys (63.3%). The mean BLL was 1.1±0.7 µg/dL and the median was 0.9 µg/dL with an IQR of (0.6–13) µg/dL. Most parents had a college level education (58.9% of fathers and 71.1% of mothers), and the majority had a monthly household income of greater than $1000. Having a father or a mother with a college degree (p=0.01 and p=0.035, respectively) and having a household income greater than $1000 (p=0.021) were associated with significantly lower BLL (table 1).

Child's health status

Most of the participants were previously healthy (65.6%). None had previously been diagnosed with lead toxicity, and only one participant had a sibling who had previously been tested for lead toxicity but had normal BLL (table 1).

Residential environment and household exposures

The mean number of people residing at the child's house was 4.7±1.5 people and the mean number of rooms was 4.5±1.7 rooms. Having more rooms at home was associated with a significantly lower BLL in the child (p=0.001). Half of the children resided in houses/buildings aged over 20 years, and 21.1% resided in houses aged over 40 years. Having ever resided in a house aged >40 years was associated with a significantly higher BLL (p=0.009). Thirty-three caregivers (36.7%) reported that it has been more than 5 years since the inside walls of the house have been painted, and 53.3% reported that there is paint visibly chipping inside the house. Most children (63.3%) resided within 300 m of pollution-generating sites (such as heavy traffic roads, car repair shops, firing ranges, etc), 24.4% resided close to construction sites and 44.4% close to factories. Residing in the vicinity of construction sites was associated with significantly lower BLL (p=0.026) (table 2).

Lifestyle and dietary exposures

Approximately one-fifth (21.1%) of the caregivers reported using tap water in preparing food/drinks for the child and 22.2% reported that their child consumes canned food. Eight caregivers (8.9%) reported that they apply kohl (lead-containing eye makeup) to the child's face. Eleven (12.2%) reported that the child receives a form of traditional medicine, and 36.7% reported being involved in rituals such as 'Bakhour' and lead pouring/melting for 'evil eye'. Receiving a form of traditional medicine was associated with significantly higher BLL (p<0.0001) (table 2).

Multivariate analysis

Multivariate logistic regression was performed to assess the association between the different characteristics of the participants and the BLL (table 3). We accounted for statistically and clinically significant participants' variables namely: age, gender, level of education of the father, level of education of the mother, household income, chronic health problems, residing in a house more than 40 years old, involvement in recreational firearm use, number of rooms in the house (excluding bathroom and kitchen), and the presence of construction sites

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Table 1 The characteristics of selected paediatric patients and their health status presenting to three hospitals in Beirut stratified by their blood lead level in comparison with the median of 0.9 µg/dL

Characteristics of participants	Total (N=90) N (%)	Below median (N=45) N (%)	Above median (N=45) N (%)	P value
Age (years) (mean±SD)	3.5±1.5	3.4±1.6	3.6±1.7	0.342
Age groups (years)				
1–2	39 (43.3)	22 (48.9)	17 (37.8)	0.499
3–4	33 (36.7)	14 (31.1)	19 (42.2)	
5–6	18 (20)	9 (20)	9 (20)	
Blood lead level (µg/dL)	0.2–4.0	0.2–0.9	0.9–4.0	N/A
Survey location				
AUBMC	63 (70.0)	31 (68.9)	32 (71.1)	0.886
SGH	20 (22.2)	11 (24.4)	9 (20)	
Bahman Hospital	7 (7.8)	3 (6.7)	4 (8.9)	
Sex				
Male	57 (63.3)	25 (55.6)	32 (71.1)	0.189
Female	33 (36.7)	20 (44.4)	13 (28.9)	
Number of siblings	1.4±1.2	1.2±0.9	1.5±1.4	0.194
Level of education of the father or caregiver 1				
Less than college	37 (41.1)	12 (26.7)	25 (55.6)	***0.010***
College level	53 (58.9)	33 (73.3)	20 (44.4)	
Level of education of the mother or caregiver 2				
Less than college	26 (28.9)	8 (17.8)	18 (40)	***0.035***
College level	64 (71.1)	37 (82.2)	27 (60)	
Monthly household income				
Less than $1000	20 (22.2)	5 (11.1)	15 (33.3)	***0.021***
More than $1000	65 (72.2)	40 (88.9)	30 (66.7)	
Health status of participants				
Child with a chronic health condition	31 (34.4)	11 (24.4)	20 (44.4)	0.075
Child known to have had iron-deficiency anaemia or to have taken iron supplements	15 (16.7)	9 (20)	6 (13.3)	0.573
Child displays pica behaviour	10 (11.1)	3 (6.7)	7 (15.6)	0.315
Child's mother or siblings having been tested for lead toxicity	1 (1.1)	1 (2.2)	0	1.000
Child's mother having consumed tobacco products during pregnancy	7 (7.8)	2 (4.4)	5 (11.1)	0.434

Bold italics type denotes p value is 0.01.
AUBMC, American University of Beirut Medical Center; N/A, not applicable; SGH, Saint George Hospital.

near the child's residence. We did not account for the 'Child receiving traditional medicine' variable since all the participants who indicated to receive traditional medicine had BLL above 0.9 µg/dL. Children residing in smaller houses were 1.7 times more likely to have a BLL above the median (p=0.043). Children residing in houses older than 40 years were found to be 8.6 times more likely to have a BLL above the median (p=0.002). Children whose caregivers were involved in recreational firing of guns were 6.1 times more likely to have a BLL that was above the median (p=0.006).

DISCUSSION

This study aimed at assessing the BLL in Lebanese children aged 1–6 years from three different hospitals and identifying subgroups at risk of exposure. Similar to the progression seen in the USA,[16 17] our study findings suggest that BLLs have declined among Lebanese children compared with the study in 2003, where 79% of the samples showed levels higher than 5 µg/dL.[13] This decrease is more profound than the one seen in Palestine, as depicted by a study done in 2013, showing that 4.5% of children had BLL above 10 µg/dL,[18] compared with 5.2% in a previous study.[19] Additionally, our sample's mean of BLL was lower than the pooled mean BLL reported in a systematic review for studies in 34 low/middle-income countries.[20] The decrease in lead levels in Lebanon can be attributed to various factors which are detailed in the following sections.

Socioeconomic and educational status

The socioeconomic status had an impact on lead levels. A monthly household income of greater than $1000, which is above the poverty line of $420, was associated with a lower BLL. Moreover, the number of rooms at home was inversely associated with BLL, and this could be an indirect indicator of socioeconomic status as people with higher income are usually capable of residing in larger houses than others. In fact, even at the multivariate analysis level, children residing in smaller houses were 1.7 times more likely to have a BLL above the median (p=0.043). Furthermore, residing close to construction sites was associated with significantly lower BLL. This could be due to the fact that construction sites might predict that the neighbourhoods where the children are residing are relatively newer, which could indicate a relatively better socioeconomic status, where parents can afford living in a new house.

Moreover, a higher level of education of either of the primary caregivers was associated with a lower BLL. In fact, the parental educational level has been associated with a better health status in Middle Eastern children.[21]

Environmental factors

Residing in houses older than 40 years was associated with having higher BLL. In fact, at the multivariate level of analysis, these children were found to be 8.6 times more likely to have a BLL above the median (p=0.002). It is well established that chipping paint, especially old lead-containing paint, is a major source of lead exposure.[1 10 22 23] In fact, old decaying paints in developing countries including Lebanon were shown to contain exceedingly high levels of lead, some brands reaching levels as high as 537 times the amount of lead found in paints sold in the USA.[11] Moreover, tap water delivered by lead-soldered pipes can also be another source of lead,[13] particularly in old houses where the pipes would have decayed with time, thereby increasing lead concentration in the household's consumed water.

In 1988, law number 64/1988 was passed in Lebanon to protect the environment; however, although it included lead-containing products on the list of hazardous pollutants, it did not contain any specific items banning lead-containing products.[24] On the other hand, in 2001, another Lebanese law (number 341/2002) was passed and it prohibited the use of lead-containing gasoline in Lebanon as of 1 January 2002.[14] In their study, Nuwayhid *et al* recruited patients between 1997 and 1998. Back then, law number 341/2002 had not been passed yet, and this could be one of the major factors explaining the decrease in the mean BLL since then. Similar to the ban on leaded gasoline, introducing and enacting laws to eliminate the use of lead-containing

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Global child health

Table 2 The residential environment and household exposures and lifestyle and dietary exposures of selected paediatric patients presenting to three hospitals in Beirut stratified by their blood lead level in comparison with the median of 0.9 µg/dL

Residential environment and household exposures	Total (N=90) N (%)	Below median (N=45) N (%)	Above median (N=45) N (%)	P value
Number of people living permanently at home	4.7±1.5	4.8±1.3	4.6±1.6	0.618
Number of rooms in the house (excluding the bathroom and kitchen)	4.5±1.7	5.1±2.0	3.9±1.1	***0.001***
Smokers at home	63 (70.0)	31 (68.9)	32 (71.1)	1.000
Type of smoking (choose multiple)				
Cigarettes	44 (69.8)	21 (46.7)	23 (51.1)	0.833
Hookah or water pipe	28 (44.4)	13 (28.9)	15 (33.3)	0.820
Cigar	3 (4.8)	2 (4.4)	1 (2.2)	1.000
Other	3 (4.8)	3 (6.7)	0	0.242
Parents smoking in closed areas	41 (45.6)	21 (46.7)	20 (44.4)	1.000
Residence age in which the child currently resides				
<20 years	45 (50)	25 (55.6)	20 (44.4)	0.399
>20 years	45 (50)	20 (44.4)	25 (55.6)	
Last time the walls of the house (or any room) were painted				
<5 years	57 (63.3)	30 (66.7)	27 (60)	0.662
>5 years	33 (36.7)	15 (33.3)	18 (40)	
Previous child residency that was more than 40 years old	19 (21.1)	4 (8.9)	15 (33.3)	***0.009***
Visible paint chipping in any part of the house	48 (53.3)	22 (48.9)	26 (57.8)	0.526
Presence of pollution-generating sites within 300 m of residence	57 (63.3)	31 (68.9)	26 (57.8)	0.382
Presence of construction sites within 300 m of residency	22 (24.4)	16 (35.6)	6 (13.3)	***0.026***
Presence of factories within 300 m of residency	40 (44.4)	20 (44.4)	20 (44.4)	1.000
Lifestyle and dietary exposures				
Presence of a water well that is used for the building	47 (52.8)	20 (45.5)	27 (60)	0.205
Presence of a tap or well water used for the child food or drinks	19 (21.1)	9 (20)	10 (22.2)	1.000
Child consuming canned (metal) food	20 (22.2)	9 (20)	11 (24.4)	0.800
Use of trusted spice sources	61 (67.8)	32 (71.1)	29 (64.4)	0.652
Child eating in or playing with pottery	4 (4.4)	2 (4.4)	2 (4.4)	1.000
Applying kohl to the child	8 (8.9)	5 (11.1)	3 (6.7)	0.714
Child using or playing with any other cosmetics	30 (33.3)	16 (35.6)	14 (31.1)	0.823
Child using or playing with any jewellery	17 (18.9)	6 (13.3)	11 (24.4)	0.281
Child receiving traditional medicine	11 (12.2)	0	11 (24.4)	***<0.0001***
Performing lead melting for 'evil eye' or use of Bakhour	33 (36.7)	14 (31.1)	19 (42.2)	0.382
History of child travel	31 (34.8)	19 (43.2)	12 (26.7)	0.123
Involvement of the child or parents in recreational firearm use	20 (22.2)	7 (15.6)	13 (28.9)	0.204
Involvement of the child or parents in car/home repair activities	22 (24.4)	12 (26.7)	10 (22.2)	0.807
Involvement of the child or parents in painting activities	4 (4.4)	2 (4.4)	2 (4.4)	1.000

Bold italics type denotes p valus is 0.01.

Table 3 Multivariate logistic regression analysis to assess the association between the different characteristics of the participants and the blood lead level*

	aOR	Significance	95% CI
Level of education of the father or caregiver 1	0.4	0.089	0.12 to 1.16
Residing in a house more than 40 years old	8.6	***0.002***	2.22 to 33.45
Involvement in recreational firearm use	6.1	***0.006***	1.69 to 22.33
Number of rooms in the house (excluding bathroom and kitchen)	0.6	***0.043***	0.38 to 0.98

Bold italics type denotes p valus is 0.01.
*Accounting for: age, gender, level of education of the mother or caregiver 2, household income, chronic health problems, presence of construction sites within 300 m of home.
aOR, adjusted OR.

paint could be beneficial by further reducing lead exposure.[1 22] In fact, in the USA, it was estimated that around 88% of children between 1 and 5 years of age had elevated BLLs in 1980.[16] This prevalence dropped massively to around 3% in 1995, and to less than 1% in the year 2014.[16 17] This decrease is due to multiple precautions such as eliminating lead-containing paint and phasing out leaded gasoline.[1 22]

Parental practices

The use of traditional medicine was associated with significantly higher BLL. In fact, although we only had 11 children who were receiving traditional medicine, they all had above-median BLL. This result is worrisome as such therapies have not been thoroughly studied and are regulated as dietary supplements rather than drugs. They also contain some products including lead and other metals which are toxic to the human body.[25] There are multiple reports in literature about lead poisoning incidents that were attributed to the use of traditional medicine.[26–28] In fact, in 2012 an outbreak of lead poisoning occurred in Durban, South

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Africa, which was attributed to the use of traditional medication that turned out to contain high levels of lead.[28] This calls for regulations that should better control the use of such medication, and awareness campaigns that would inform people about their side effects.

Children whose caregivers were involved in recreational firearm use were 6.1 times more likely to have an above-median BLL. Although this was not statistically significant at the bivariate level, it was statistically significant at the multivariate level after controlling for other confounders (p=0.006). We noticed that the 'Number of rooms in the house (excluding bathroom and kitchen)' variable has a confounding effect on the correlation between the 'Involvement in recreational firearm use' and the BLL. The use of recreational firearms has been associated with elevated BLL in multiple studies.[29–31] A review done in 2017 concluded that all participants who engaged in recreational firearm use had elevated BLL.[31] Given that, children of parents who engage in such activities might be indirectly exposed to lead from their parents either through particles remaining on clothing or skin, or by other mechanisms. Informing people who participate in these activities about the potential health hazards of lead on them and their families might motivate them to develop safe-use habits such as wearing disposable personal protective equipment while using the firearms and showering right after.

Future steps

It would be important to educate primary care physicians and paediatricians on the importance of identifying risk factors of lead exposure in their paediatric patients. It might be beneficial for physicians to screen children using questions about the socioeconomic status, environmental exposures, the use of traditional remedies, among others. This could identify children who are at highest risk of lead exposure and might warrant blood screening and/or interventions.

Limitations

This study assessed the paediatric population in three centres all located in the capital of Lebanon. The results might therefore not be generalisable to more rural areas away from the capital. However, we enrolled patients from outpatient clinics who generally come from rural areas. Furthermore, we did not assess the cognitive ability of the patients at their enrolment. Moreover, due to the COVID-19 pandemic, patient recruitment had to be halted prematurely as it became increasingly difficult to be present at different hospitals and to transport blood products between institutions.

CONCLUSION

BLLs have declined among Lebanese children and this could be attributed to multiple factors including the introduction of the law banning leaded gasoline in Lebanon. We encourage the public health authorities to conduct a larger study with a nationally representative sample to better characterise the lead levels in children residing in different areas in Lebanon. However, as there is no safe BLL, it remains crucial to have a clear regulation in place to eliminate the use of lead additives in all products including leaded paint.

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