

Neurological Effect of Lead Exposure in Children

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Abstract

Lead poisoning is one of the burning issues in Bangladesh. This study assessed the relation of blood lead level with IQ and peripheral nerve function in environmental lead exposed primary school children in Dhaka.

Blood lead level (BLL) was measured in 84 primary school children in an urban industrial area of Dhaka. IQ was measured with Wechsler Intelligence Scales- Revised for children. Electrophysiological evaluation was done in 31 children.

Verbal, Performance and Full scale IQ had a negative correlation with blood lead level ($p < 0.001$). Decrement in Verbal, Performance and Full scale IQ associated with 1 microgram per deciliter increase in blood lead level were 0.99, 0.86 and 0.95 respectively ($p < 0.001$). None had clinical features of neuropathy. Statistical analysis also did not show any significant difference in NCS between children with normal and elevated BLL (p value > 0.05).

It was found that IQ of children decreased in a linear trend with increasing blood lead level. This study did not find any clinical or electrophysiological evidence of peripheral nerve dysfunction in the environmental lead exposed children.

Key words: IQ, neuropathy, lead exposure, children

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Introduction

Dhaka, Bangladesh, was discovered to have one of the highest air lead level in the world¹. Almost 90% of the children has elevated blood lead level (BLL) in Dhaka². BLL at the urban industrial area of Bangladesh is significantly higher than those at the rural and urban nonindustrial areas³. Diagnosis of lead exposure is based on blood lead level measured in micrograms of lead per deciliter of blood ($\mu\text{gm}/\text{dl}$). World Health Organization (WHO) states that BLL of $10 \mu\text{gm}/\text{dl}$ or above is abnormal⁴. The purpose of this study was to assess IQ and peripheral nerve function in children of urban industrial area of Dhaka to evaluate the neurological effect of environmental lead exposure.

Lead poisoning can occur from both occupational and environmental source⁵. Lead is toxic to many organs and tissues including nervous systems⁶. Lead is much more harmful to children than adults because it can affect children's developing nerves and brains⁷. Peripheral nervous system (PNS) effects are more prominent in adults and central nervous system (CNS) effects are more prominent in children⁸. While heavy exposure to inorganic lead is capable of inducing symptomatic neuropathy, subclinical neuropathy is more common⁹⁻¹². This study assessed the relationship of blood lead level with IQ for CNS effect and peripheral nerve function for PNS effect in lead exposed children.

An intelligence quotient (IQ) is a score derived from one of several different standardized tests designed to assess intelligence. The scoring of modern IQ tests such as the Wechsler Intelligence Scale is now based on standard scoring of the subject's rank order on the test item content with the median score set to 100, and a standard deviation of 15. The effect of lead on children's cognitive abilities takes place at very low levels¹³. Between the blood lead levels of 5 and $35 \mu\text{gm}/\text{dl}$, an IQ decrease of 2-4 points for each $\mu\text{g}/\text{dL}$ increase is reported in children.

The six East Asian nations all have IQ in the range between 105 and 108. The 29 European nations all have IQs in the range between 92 and 102. The 19 nations of sub-Saharan Africa all have IQ in the range between 59 and 73. The average estimated national IQ of Bangladesh is 81 and measured national IQ of India is 81. In Bangladesh, 10 year old children showed their mean Full scale IQ, Verbal IQ and Performance IQ were 64 ± 11.6 , 70.8 ± 12.2 , 63.9 ± 11.9 respectively¹⁴.

Materials and Methods

The study was conducted from January 2009 to December 2010 in BSMMU. Study population was selected from a primary school, where the tannery industries of Dhaka are located. Blood lead level (BLL) was measured in 84 children of 6 to 12 years age. Patients suffering from diabetes mellitus, hypothyroidism, speech and hearing abnormalities, children with family history of peripheral neuropathy were excluded from the study. IQ levels were measured in 84 children. 31 children agreed to do electrophysiological evaluation. Denial of consent to perform NCS was the primary reason for not performing the test.

BLL was measured by using a portable Lead Care instrument (ESA Inc, Chelmsford, MA, USA) from venous blood (0.5 ml). The instrument has been approved by the US Food and Drug Administration (FDA), and is being used in many health centers in the United States.

IQ levels were measured by psychologist, well trained in this field with the use of Wechsler Intelligence Scales for Children –Revised (WISC-R) suitable for children ≥ 6 years of age. WISC-R consisted of five verbal subtests which together provided a verbal IQ score and a similar number of performance subtests that together provided a performance IQ score. The subtests were administered in standardized environments according to standardized procedures. Summation of these weighted items across verbal, performance and full scale raw scores were done and then transformed these into measures of estimated verbal, performance, and full scale IQ, using procedures presented in the test manual.

Nerve conduction studies were performed by a single neurophysiologist by NIHON KOHDON (Neuropack E) machine. Sensory nerve action potentials were recorded using an antidromic stimulus. Surface electrodes were used for recording and for stimulation. NCS was done in cross limb (right upper and left lower limb).

All data was recorded systematically in preformed data collection form and quantitative data was expressed as mean and standard deviation. Statistical analyses of the results were obtained by using window based computer software devised with Statistical Packages for Social Sciences (SPSS-16). Statistical tests for significance of difference were done using student's t test. Multiple logistic regression analysis was done to evaluate the risk factors. ANOVA and then perform Bonferroni test for comparison between two groups.

Results

The current study was conducted in 84 primary school children of 6 to 12 years age. BLL range was 3.6 to 31.9 $\mu\text{gm}/\text{dl}$ with mean BLL of 15.33 ± 3.54 . 52 were boys with mean BLL of 15.45 ± 3.67 . 32 were girls with mean BLL of 15.15 ± 3.38 . Of the 84 children, 78 (92.8%) had elevated BLL ($\geq 10 \mu\text{gm}/\text{dl}$).

Mean (\pm SD) of verbal IQ among children with blood lead level of ≤ 10 , 10-20, and >20 micro gm /dl was 83.00 ± 9.10 , 73.62 ± 5.82 , and 65.40 ± 4.35 respectively. Mean (\pm SD) of performance IQ among children with blood lead level of ≤ 10 , 10-20 and >20 micro gm /dl was 78.67 ± 7.94 , 71.34 ± 6.13 , and 67.20 ± 4.96 respectively. Mean (\pm SD) of full scale IQ among children with blood lead level of ≤ 10 , 10-20 and >20 micro gm /dl was 78.50 ± 6.06 , 70.01 ± 3.97 , and 63.30 ± 2.67 respectively.

Statistical test was done by ANOVA and then perform Bonferroni test for comparison between two groups. This shows statistically significant difference of verbal IQ, performance IQ and full scale IQ with blood lead level between the groups ($p=0.001$) shown in Table 1.

Table 1: statistical analysis between the groups showing p values

	p value		
	Verbal IQ	Performance IQ	Full scale
<10 vs. 10-20 vs. >20	0.001	0.002	0.001
<10 vs. 10-20	0.001	0.019	0.001
<10 vs. >20	0.001	0.002	0.001
10-20 vs. >20	0.001	0.15	0.001

In this study, it was found that IQ of children decreased in a linear trend with increasing blood lead level. After adjustment for sex, Hb%, family monthly income, occupation of father and mother, educational level of father and mother Verbal, Performance and Full scale IQ had a negative correlation with blood lead level ($p<0.001$) shown in table 2. Decrement in Verbal, Performance and Full scale IQ associated with 1 microgram per deciliter increase in blood lead level was 0.99, 0.86 and 0.95 respectively ($p<0.001$).

Table 2: Correlations of verbal, performance and full scale IQ with blood lead level

Blood lead level vs	r value	p value
Verbal IQ	-0.558	<0.001
Performance IQ	-0.544	<0.001
Full scale IQ	-0.738	<0.001

Clinical evaluation for evidence of peripheral neuropathy was done in 84 students. Symptoms related to peripheral nerve dysfunction were found in none of the subject. Clinical signs of peripheral neuropathy were also absent in all the children. Nerve function recordings were within normal level in all groups of students. Statistical analysis also did not find any significant difference in NCS between the children with normal and elevated BLL. The results are shown in table 3 and table 4.

Table 3- Comparison of mean (\pm SD) motor NCS between normal and elevated BLL group (NS = not significant, ms = millisecond, mv = millivolt, m/s = meter/ second)

Name of nerve	Motor latency (ms)			Motor amplitude (mv)			Motor conduction velocity (m/s)		
	BLL < 10 μ gm/ dl	BLL \geq 10 μ gm/ dl	P value	BLL < 10 μ gm/ dl	BLL < 10 μ gm/ dl	P value	BLL \geq 10 μ gm/ dl	BLL \geq 10 μ gm/ dl	P value
Median	2.77 (0.24)	2.87 (0.41)	0.251 NS	13.50 (4.02)	13.76 (4.50)	0.550 NS	60.23 (6.53)	60.93 (5.75)	0.712 NS
Ulnar	1.89 (0.29)	2.14 (0.38)	0.249 NS	7.47 (1.37)	8.25 (1.86)	0.201 NS	60.56 (5.53)	60.08 (7.79)	0.290 NS
Tibial	3.00 (0.22)	2.92 (0.29)	0.330 NS	19.91 (4.93)	17.87 (4.66)	0.962 NS	51.29 (4.04)	49.76 (4.08)	0.935 NS
Peroneal	3.74 (0.73)	3.64 (0.76)	0.686 NS	4.69 (1.78)	4.81 (1.69)	0.808 NS	58.44 (9.05)	52.98 (7.67)	0.559 NS

Table 4- Comparison of mean (\pm SD) sensory NCS between normal and elevated BLL group (NS = not significant, ms = milli second, μ v = micro volt, m/s = meter/ second)

Name of nerve	Sensory latency (ms)			Sensory amplitude (μ v)			Sensory conduction velocity (m/s)		
	BLL < 10 μ gm/ dl	BLL \geq 10 μ gm/ dl	P value	BLL < 10 μ gm/ dl	BLL < 10 μ gm/ dl	P value	BLL \geq 10 μ gm/ dl	BLL \geq 10 μ gm/ dl	P value
Median	1.97(0.19)	2.03(0.22)	0.458 NS	32.42 (7.63)	31.42(8.35)	0.890NS	57.44(8.89)	55.83(7.86)	0.519 NS
Ulnar	1.70(0.20)	1.70(0.22)	0.585 NS	30.57(7.46)	29.46(7.82)	0.473 NS	58.77(2.53)	56.70(5.86)	0.602 NS
Sural	1.88 (0.16)	1.84(0.21)	0.187 NS	34.43(6.48)	32.66(8.59)	0.458 NS	54.37(3.30)	53.36(3.19)	0.708 NS

Discussion

IQ was measured over eighty four children. The mean BLL of 84 students was $15.33 \pm 3.54 \mu\text{gm/ dl}$; boys had $15.45 \pm 3.67 \mu\text{gm/ dl}$, and girls had $15.15 \pm 3.38 \mu\text{gm/ dl}$. In a study by Lanphear(2005)¹⁵ showed blood lead level varied by gender, educational level of parents, poverty index ratio and race; mean BLL was higher for males than females and varied inversely with poverty index ratio and educational level of parents. In present study BLL was high in boys, in income group <5000Tk/month, in group of mothers with upto primary education, in group of fathers with upto primary education and in group of mothers with occupation of service including garments worker.

Mean verbal IQ, performance and full scale IQ was 73.31 ± 6.98 , 71.31 ± 6.54 , 69.82 ± 53 respectively. Wasserman (2005)¹⁴ studied on 142 children 10 years old, in Arahazar, Bangladesh showed their mean Full scale IQ, Verbal IQ, and Performance IQ were 64 ± 11.6 , 70.8 ± 12.2 and 63.9 ± 11.9 respectively. In the current study, it was found that IQ of children decreased in a linear trend with increasing blood lead level, which is consistent with

previous studies (Lanphear, 2005; National Research Council, 1993; Schwartz, 1994; Pocock. 1994; Chen, 2005; Herbert, 1990)¹⁵⁻²⁰.

After adjustment for sex, Hb%, monthly income, occupation of father, occupation of mother, educational level of father, educational level of mother, verbal IQ, performance and full scale IQ have negative association with blood lead level ($p < 0.001$). The findings of the present study are consistent with previous studies (Herbert, 1990; Bellinger, 2004; Bellinger, 2008)²⁰⁻²².

Several previous studies showed different degrees of loss of IQ points for each microgram per deciliter increase in BLL e.g. a 0.87 point decrease in IQ for each microgram per deciliter increase in BLL (Canfield, 2000)²³; a 0.99 point decrease in IQ for each microgram per deciliter increase in BLL (Lanphear, 2005)¹⁵. In present study, decrement in verbal IQ, performance and full scale IQ associated with 1 microgram per deciliter increase in blood lead concentration was 0.99, 0.86 and 0.95 respectively.

Traditionally the neuromuscular disorder associated with lead poisoning has been purely motor. But after a critical

review and meta-analysis on NCS in 32 studies on asymptomatic lead workers, Davis and Svendsgaard(1990)²⁴ concluded that there were no substantive differences in NCS between the asymptomatic workers and normal controls. This result is consistent with present study findings as no substantive differences were found in NCS between the asymptomatic rise of BLL and normal controls.

Giann-Horng Yeh (1995)²⁵ reported that early conduction abnormalities in lead neuropathy are manifested by prolonged distal latencies rather than a slowing of NCV. In this study no abnormalities were found in distal latency. But all the participants were asymptomatic and BLL of them were not as much elevated compared to their study.

Joel Schwartz (2001)²⁶ performed clinical and electrophysiological evaluation in 202 five to nine year-old children living near a lead smelter in Idaho. Blood lead levels ranged from 13 to 97 µgm /dl. There was no clinical feature of neuropathy in those children. But asymptomatic increase of BLL was associated with slowing of nerve conduction velocity in motor nerves. In this study, the age group was nearly similar (6 to 12 year). BLL was much lower (3.6-31.9 µgm /dl) in the study comparison to previous study. No clinical feature of neuropathy was found in the children; which is similar to other study finding. No difference was found in electrophysiological evaluation; which is contrary to previous study finding. One explanation to this finding is that, BLL of this current study subjects were significantly low.

In a developing country like Bangladesh, lead poisoning seems to be a matter of concern both in occupational and environmental aspects. In this study higher blood lead level had a significant negative impact on IQ level of school children and impairs their neuropsychological development. No significant association was found between BLL and neuropathy probably because the BLL of the environmental lead exposed children was not that much raised and the duration of exposure was small to cause neuropathy.

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