

Correlation of blood lead level and intelligence quotient in children

Lilian Gunawan, Nurhayati Masloman

Abstract

Background Lead poisoning is a source of health problems in humans. A chronic complication of lead poisoning in children is permanent intellectual impairment.

Objective To assess for a correlation of blood lead levels and intelligence quotient (IQ) in children.

Methods A cross-sectional study was performed in children aged 6 to 8 years in the Talawaan (a rural area) and Wenang (an urban area) Districts, North Sulawesi, from April to July 2012. Blood lead levels were measured using the graphite furnace atomic absorption spectrometry technique; and intelligence was measured with the Wechsler Intelligence Scale for Children-Indonesian version.

Results There were 50 subjects from the Talawaan District and 54 subjects from the Wenang District in this study. The mean blood lead level in the Talawaan District subjects was significantly higher than that of the Wenang District subjects [25.8 (SD 16.98) $\mu\text{g/dL}$ vs 11.4 (SD 13.81) $\mu\text{g/dL}$, respectively; ($P < 0.001$)]. There was a weak negative correlation between blood lead level and IQ in the Talawaan District children ($P = 0.038$; $r = -0.3$). As such, there was a 0.05 IQ point decrement associated with each increase of 1 $\mu\text{g/dL}$ in blood lead level in Talawaan District children. However, there was no correlation between blood lead level and IQ in the Wenang District children ($P = 0.42$; $r = 0.03$).

Conclusion There is a weak negative correlation between blood lead level and IQ in children living in a rural area, however, this correlation is not found in children living in an urban area.

[*Paediatr Indones*. 2014;54:127-31.]

Keywords: lead, IQ, children

Lead poisoning remains a global health hazard, especially in developing countries. The main source of lead pollution is found in our living environment.¹⁻³ Children are particularly susceptible to lead poisoning, because they have a higher absorption rate for lead compared to adults, and they have an immature blood-brain barrier. Lead can interfere with other essential metals involved in neurotransmitter metabolism. In addition, lead has a long half-life and is excreted slowly from the body. Chronically elevated blood lead level during brain development results in cognitive impairment, which is mostly irreversible even after the exposure has been eliminated.^{4,5} As such, early detection and intervention in those with high blood lead levels are necessary.

Children in less developed countries are more vulnerable to the effects of lead on cognitive impairment, because they may also have caloric and micronutrient deficiencies, limited resources for early intervention and are less likely to be examined for lead exposure.⁶ Several studies have shown a negative correlation between lead poisoning and intelligence

From the Department of Child Health, Sam Ratulangi University Medical School, Manado, Indonesia.

Reprint requests to: Lilian Gunawan, Department of Child Health, Sam Ratulangi University Medical School, Prof. Dr. R. D. Kandou Hospital, Jl. Raya Tanawangko, Manado, Indonesia. Tel. +62 (431) 821652. Fax. +62 (431) 859091. E-mail: liliangunawan@hotmail.com.

quotient (IQ) in children, regardless of the wide age range, hemoglobin levels, and nutritional status.⁷⁻¹⁰ Previous studies in Indonesia had shown a high blood lead level among children in urban areas, however, the long term effects on children's intelligence has not been established.¹¹⁻¹³ The role of the environment in a child's intelligence is well known, however, accumulating effects of lead poisoning has never been determined. The aim of this study was to assess for a correlation between blood lead level and IQ in children.

Methods

A cross-sectional study was held in the Wenang District, Manado, and Talawaan District, North Minahasa, from April to June 2012. A random sampling method was conducted among 6 to 8-year-old first graders from 7 chosen schools, resulting in 54 children from the Wenang District and 50 children from the Talawaan District who met the inclusion criteria.

This study was conducted in two different environments to assess for a correlation between blood lead level and IQ of children living in rural and urban areas. Wenang District represented an urban area in Manado with a high risk of exposure to lead from leaded gasoline combustion in vehicle exhaust, whereas the Talawaan District represented a rural area with less exposure to lead from vehicles. The blood lead level of Talawaan District children would presumably be the result of lead exposure from other environmental sources. The US Centers for Disease Control 1991 guidelines for safe blood lead levels was used as a reference for our subjects.¹⁴

The inclusion criteria were healthy, non-anemic, active, school-aged children who lived in the Wenang or Talawaan Districts during sample collection. Exclusion criteria were other risk factors of developmental delay, such as prior central nervous system infection, prematurity, neonatal asphyxia, neonatal jaundice, low birth weight, or congenital abnormalities. Children with bone fractures or blood abnormalities that occurred within the 3 months prior to sample collection were excluded. Written informed consent was obtained from the children's parents after they received a complete explanation of this study.

Socioeconomic and demographic information was obtained through questionnaires, while the history of previous illnesses, birth history, and development of the child were obtained by parent interviews. Subjects underwent complete physical examinations and anthropometric measurements before blood specimens were obtained.

One blood specimen (8 mL) was taken from each subject. Blood lead levels were determined using a graphite furnace atomic absorption spectrometry (GFAAS) technique,¹⁵ with a 0.1 µg/dL limit of detection for lead. Intelligence quotients of the children were measured using the Weshcler Intelligence Test for Children-Indonesian version.

Results were analyzed with T-test to compare mean blood lead levels and IQs of the children in Talawaan and Wenang. Pearson's correlation test was used to assess for a correlation between blood lead level and IQ. For simple correlation analysis, we used SPSS version 20 software. A P value of <0.05 was considered to be statistically significant.

Results

A total of 104 children, consisting of 50 children from the Talawaan District and 54 children from the Wenang District, were included in the study. **Table 1** shows the characteristics of subjects. The mean blood lead level of Talawaan District children was significantly higher than that of Wenang District children (25.8 vs 11.4 mg/dL, respectively; $P < 0.001$) (**Table 2**). There were significantly more children in the Talawaan District with blood lead level ≥ 10 mg/dL compared to those in the Wenang District (90% vs

Table 1. Characteristics of subjects

| Characteristics | Talawaan District n = 50 | Wenang District n = 54 |
|----------------------------------|-----------------------------|---------------------------|
| Mean age (SD), months | 81.7 (5.33) | 79.7 (4.77) |
| Gender, n (%) | | |
| Female | 22 (44.0) | 29 (53.7) |
| Male | 28 (56.0) | 25 (46.3) |
| Mean birth weight (SD), kg | 3.2 (0.46) | 3.4 (0.45) |
| Mean body weight (SD), kg | 20.2 (2.75) | 20.9 (2.25) |
| Mean height (SD), cm | 115.6 (6.42) | 115.1 (4.91) |
| Mean BMI (SD), kg/m ² | 15.1 (1.16) | 15.8 (1.34) |
| Mean head circumference (SD), cm | 50.3 (1.22) | 49.7 (0.91) |

Table 2. Blood lead levels and IQ of subjects

| Variables | Talawaan Distrik n = 50 | 95% CI | Wenang Distrik n = 54 | 95% CI | P value |
|-----------------------------------|----------------------------|--------------|--------------------------|--------------|---------|
| Mean blood lead level (SD), µg/dL | 25.8 (16.98) | 21.0 to 30.7 | 11.4 (13.81) | 7.7 to 15.2 | <0.001 |
| Mean total IQ (SD), points | 96.1 (3.13) | 95.2 to 97.0 | 97.3 (2.62) | 96.6 to 98.0 | 0.032 |
| Mean verbal IQ (SD), points | 43.9 (2.42) | 43.2 to 44.6 | 44.4 (2.61) | 43.6 to 45.0 | 0.203 |
| Mean performance IQ (SD), points | 50.2 (2.69) | 49.4 to 50.9 | 51.4 (2.20) | 50.8 to 52.0 | 0.008 |

31.5% children, respectively; $P < 0.001$). Furthermore, the mean total IQ level of Talawaan District children was significantly lower than that of Wenang District children (96.1 vs 97.3 points, respectively; $P = 0.032$). Also, the mean performance IQ level of Talawaan District children was significantly lower than that of Wenang District children (50.2 vs 51.4 points, respectively; $P = 0.008$). However, there was no significant difference in verbal IQ between districts (43.9 vs 44.3 points, respectively; $P = 0.203$). These results are shown in **Table 2**.

Statistical analysis revealed a weak inverse correlation between blood lead levels and mean total IQ of the Talawaan District children ($r = -0.3$; $P = 0.038$). This correlation was best approximated by the formula $Y = 97.2 - 0.05X$, when Y was total IQ and X was blood lead level. There was a 0.05 IQ point decrement associated with an increase of 1 µg/dL in blood lead level of Talawaan District children, as shown

in **Figure 1**. There was no significant correlation between blood lead levels and IQ of Wenang District children ($r = 0.03$; $P = 0.42$).

Discussion

The blood lead levels of the Wenang District children were moderately high, but for the most part, lower than that observed in other Indonesia town. However, these results were higher than the first study of blood lead level in Manado by Wagiu *et al.*, where there were more children with blood lead level ≥ 10 µg/dL (17% vs 2.5%).¹⁶ The three primary schools in the Wenang District are located in urban areas with high traffic density. The air lead level in Manado in 2005 (1.789 µg/dL) exceeded the recommended levels determined by the Environmental Protection Agency (1.5 µg/dL) and the World Health Organization (1 µg/dL).^{17,18}

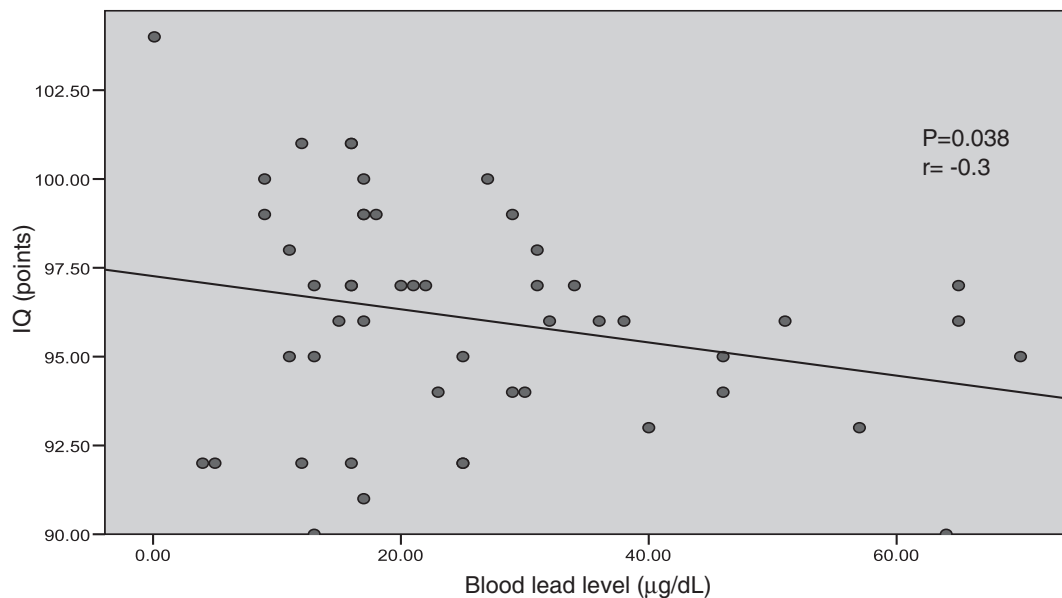


Figure 1. Correlation between blood lead level and IQ of Talawaan District children
This correlation presented as: $Y = 97.2 - 0.05 X$

Our blood lead level results were consistent with a modest effect of location, with respect to leaded gasoline exhaust released from the vehicles. The increased number of vehicles results in more lead exhaust released from leaded gasoline and inhaled by children.

Blood lead levels of the Talawaan District children were significantly higher than that of Wenang District children. These results were even higher than those observed in all previous studies in Indonesia. Four primary schools in the Talawaan District are located in rural areas with minimal traffic pollution. Unexpectedly high lead levels may be due to other sources of exposure located near those villages. Furthermore, traditional gold mining is run by local people located 2 km from those villages. Many trucks with travel on the main roads of those villages carrying raw material for gold mining. This material exposes children to leaded dust which can be inhaled. Motorcycles, as the main means of transport in those villages, also worsen the air pollution. The amalgamation technique of gold purification results in waste products, known as tailing, which contains lead, mercury, arsenic, and zinc. Those toxic metals may be a source of land and water pollution.¹⁹ The study on the Dimembe gold mine showed that acidic waste and high levels of metals exceeded those recommended by the Ministry of Environment for field watering.²⁰ Also, Rumengan reported a higher content of waste products from gold mining in the Talawaan River compared to others.²¹ In addition, Barbosa *et al.* reported lead intoxication in children living near a gold mining area.¹⁷ The US CDC reported death due to lead poisoning and increased numbers of children with blood lead level of ≥ 45 mg/dL.²²

The mean total IQ of the children in the urban area (Wenang District) was significantly higher than that of children in the rural area (Talawaan District). The mean performance IQ in the urban area was also higher than that in the rural area. The verbal IQs in both districts were lower compared to performance IQs. Similarly, a previous study showed that in terms of the initial impairment that might be caused by lead poisoning, the verbal IQ may be influenced by lower blood lead levels, whereas performance IQ started decreasing at higher blood lead levels, accompanied by an increase in hyperactivity score.²³⁻²⁶

There was a weak correlation between blood lead level and IQ of Talawaan District children, but this correlation was not found in Wenang District subjects. This difference may be due to the presence of higher blood lead levels in Talawaan compared to Wenang subjects. These findings were similar to a study by Zalina *et al.*,⁹ however, showed less strength correlation than previous studies.^{26,27} Other potential factors influencing intelligence, such as genetics and socioeconomic background, were difficult to control for. Parental education and access to education and information may play a role in child intelligence. Also, the postulation that gold mining was the main source of lead exposure in this study remains unconfirmed. Further studies are needed to address these limitations.

This is the first study in Manado to assess for an association between blood lead level and its effect on IQ in children. A strength of this study was the GFAAS method for blood lead level analysis, which has a better lower limit of lead detection compared to previous studies. The narrower range of subjects' age in our study eliminated the influence of increasing blood lead deposition according to age. A limitation of this study was not adjusting for other potential influencing factors, such as genetic and social influences, differences in parental education and access to information, which may have affected the results.

The study show there is an urgent need for regular monitoring of blood lead levels in Indonesian children. Monitoring may help us identify those with toxic levels, as determined by the CDC. Prevention and early treatment should be started before the toxic effect of lead becomes irreversible. Also, there is a need for an epidemiological study to determine the source of lead exposure in the rural area of Talawaan District.

References

1. Binns HJ, Campbell C, Brown MJ, Centers for Disease Control and Prevention Advisory Committee on Childhood Lead Poisoning Prevention. Interpreting and managing blood lead levels of less than 10 $\mu\text{g}/\text{dL}$ in children and reducing childhood exposure to lead: recommendations of the Centers for Disease Control and Prevention Advisory Committee on Childhood Lead Poisoning Prevention. Pe-

- diatrics. 2007;120:1285-98.
- American Academy of Pediatrics - Committee on Environmental Health. Screening for elevated blood lead levels. *Pediatrics*. 1998;101:1072-8.
 - Advisory Committee on Childhood Lead Poisoning Prevention. Interpreting and managing blood lead level < 10 mg/dL in children and reducing childhood exposures to lead. Washington: CDC-MMWR Recommendations and Reports; 2007. p. 1-19.
 - Jin Y, Liao Y, Lu C, Li G, Yu F, Zhi X, et al. Health effects in children aged 3-6 years induced by environmental lead exposure. *Ecotoxicol Environ Saf*. 2006;63:313-7.
 - Chiodo LM, Jacobson SW, Jacobson JL. Neurodevelopmental effects of postnatal lead exposure at very low levels. *Neurotoxicol Teratol*. 2004;26:359-71.
 - Solon O, Riddell TJ, Quimbo SA, Butrick E, Aylward GP, Lou Bacate M, et al. Associations between cognitive function, blood lead concentration, and nutrition among children in the central Philippines. *J Pediatr*. 2008;237-43.
 - Canfield RL, Henderson CR, Cory-Slechta DA, Cox C, Jusko TA, Lanphear BP. Intellectual impairment in children with blood lead concentrations below 10 microg per deciliter. *N Engl J Med*. 2003;348:1517-26.
 - Lanphear BP, Dietrich K, Auinger P, Cox C. Cognitive deficits associated with blood lead concentrations < 10 µg/dL in US children and adolescents. *Public Health Rep*. 2000;115:521-9.
 - Zailina H, Junidah R, Josephine Y, Jamal HH. The influence of low blood lead concentrations on the cognitive and physical development of primary school children in Malaysia. *Asia Pac J Public Health*. 2008;20:317-26.
 - Chandramouli K, Steer CD, Ellis M, Emond AM. Effects of early childhood lead exposure on academic performance and behaviour of school age children. *Arch Dis Child*. 2009;94:844-8.
 - Albalak R, Noonan G, Buchanan S, Flanders WD, Gotway-Crawford C, Kim D, et al. Blood lead levels and risk factors for lead poisoning among children in Jakarta, Indonesia. *Sci Total Environ*. 2003;301:75-85.
 - Lestari P. Faktor-faktor yang berpengaruh terhadap kadar timbal dalam darah anak-anak sekolah di Bandung. *Jurnal Purifikasi*. 2006;7:109-14.
 - Khidri MA, Sakkir B, Sjafruddin A. Kadar timbal dalam darah pada anak-anak di kota Makassar. *Jurnal Madani FKM UMI*. 2008;1:96-106.
 - CDC. Update: Blood lead levels - United States, 1991--1994. *MMWR*. 1997; 46:607.
 - WHO. Brief guide to analytical methods for measuring lead in blood. Geneva: WHO;2011. p.4.
 - Wagiu AF, Wulur FH. Hubungan antara kadar timbal udara dengan kadar timbal darah serta dampaknya pada anak. *Sari Pediatri*. 2006;8:238-43.
 - Warouw F. Analisis hubungan kadar Pb dalam darah dengan lama kerja pedagang kaki lima di pusat kota Manado akibat pemaparan gas buangan kendaraan bermotor yang mengandung Pb [thesis]. Manado: IKM Unsrat; 2004.
 - WHO. Inorganic lead environmental health criteria. Geneva: IPCS WHO; 1995. p. 1-14.
 - Barbosa F, Fillion M, Lemire M, Passos CJ, Rodrigues JL, Philibert A, et al. Elevated blood lead levels in a riverside population in the Brazilian Amazon. *Environ Res*. 2009;109:594-9.
 - Sumual H. Karakterisasi limbah tambang emas rakyat dime-mbe kabupaten minahasa utara. *Agritek*. 2009;17:932-7.
 - Rumengan I. Dampak Biologi dari Pertambangan Emas Rakyat di Daerah Aliran Sungai Talawaan, Manahasa Utara. Makalah. Seminar masalah dan solusi penambangan emas di Kecamatan Dimembe 9 September 2004. p?
 - Jue S, Hardee R, Overman M, Mays E, Bowen A, Whichard J, et al. U.S CDC. Notes from the field: outbreak of acute lead poisoning among children aged < 5 years – Zamfara, Nigeria. *MMWR Morb Mortal Wkly Rep*. 2010;59:846.
 - Isen J. A meta-analytic assessment of Wechsler's P>V sign in antisocial populations. *Clin Psychol Rev*. 2010;30:423-35.
 - Baxter DJ, Motiuk LL, Fortin S. Intelligence and personality in criminal offenders. In: Saklfske DH, Zeidner M. *International handbook of personality and intelligence. Perspectives on individual difference*. New York: Plenum Press; 1995. p. 673-86.
 - Surkan PJ, Zhang A, Trachtenberg F, Daniel DB, McKinlay S, Bellinger DC. Neuropsychological function in children with blood lead levels < 10 µg/dL. *Neurotoxicology*. 2007;28:1170-7.
 - Lanphear BP, Hornung R, Khoury J, Yolton K, Baghurst P, Bellinger DC, et al. Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. *Environ Health Perspect*. 2005;113:894-9.
 - Kordas K, Canfield RL, Lopez P, Rosado JL, Vargas GG, Cebrian ME, et al. Deficits in cognitive function and achievement in Mexican first-graders with low blood lead concentrations. *Environ Res*. 2006;100:371-86.