p-ISSN 2086-6380
e-ISSN 2548-7949

Jurnal Ilmu Kesehatan Masyarakat, Nov2022, 13(3):350-361
DOI: https://doi.org/10.26553/jikm.2022.13.2.350-361
Available online at http://ejournal.fkm.unsri.ac.id/index.php/jikm

SERUM LEAD LEVEL AND ACADEMIC PERFORMANCE OF ELEMENTARY SCHOOL CHILDREN IN MAKASSAR CITY

Ruslan[1], Hasnawati Amqam[1*], Widia Meilia Yusuf[2], Trimuliati Nani[2], Nur Indazil Arsyi[2], Adinda Reski Ramadhani[1]

[1]Department of Environmental Health, Faculty of Public Health, Universitas Hasanuddin. Makassar City, Indonesia

[2]Faculty of Public Health, Universitas Hasanuddin, Makassar City, Indonesia

ABSTRACT

Lead exposure to children results in a negative effect on behaviour and cognitive performance. Air lead concentration might be influenced by traffic density on the road. Schools are the locations affected by traffic-related pollution. This study aims to explore the correlation between Serum Lead Levels (SLL) and academic achievement of elementary school students, comparing the distance of the school from the road. This cross-sectional study included 54 5th and 6th-grade students from two schools that differed in the distance from the main road. We observed the students' SLL with laboratory analysis and academic performance from the final score of five subjects. The mean difference of SLL and academic achievement between the two schools were performed using the Mann-Whitney U test, and the correlation between lead concentration and academic performance using the Spearman-Rho test. This study observed that all students were exposed to lead with the SLL range of 0.39-5.97 µg/dL in the school which is located road side, and 0.42-6.44 µg/dL in the school far from main road. The insignificant difference in the students' SLL (p=0.43) between the two schools but significant in students-level of academic performance (p=0.03) were discovered. Serum lead level correlated negatively with academic performance. (r=-0.234, p=0.044). It is suggested to give more attention to preventing lead exposure in children through the implementation of some prevention programmes and policies.

***Keywords**: Pb, academic performance, children, school, road*

ABSTRAK

Pajanan timbal pada anak-anak dapat berdampak pada penurunan kondisi perilaku dan kognitif. Konsentrasi timbal di udara dapat dipengaruhi oleh kepadatan lalu lintas di jalan raya, Sekolah merupakan lokasi yang dapat terkena dampak dari polusi akibat kepadatan lalu lintas. Studi ini bertujuan untuk menganalisis korelasi antara kadar timbal serum dan prestasi akademik siswa sekolah dasar. Studi ini menggunakan desain potong lintang dengan melibatkan 54 siswa kelas 5 dan 6 dari dua sekolah. Kadar timbal serum didapatkan melalui analisis laboratorium. Prestasi akademik dinilai dari nilai rapor lima mata pelajaran. Perbedaan kadar timbal serum dan prestasi akademik dianalisis dengan menggunakan uji Mann-Whitney U dan Uji Spearman-Rho digunakan untuk menganalisis korelasi antara konsentrasi timbal serum dengan prestasi akademik siswa. Dari studi ini didapatkan bahwa timbal terdeteksi pada semua anak dengan kadar 0.39-5.97 µg/dLpada sekolah yang terletak di sisi jalan raya dan 0.42-6.44 µg/dL pada sekolah yang berjarak jauh dari jalan raya. Ditemukan perbedaan yang tidak signifikan pada kadar timbal serum (p=0.43) tetapi signifikan pada prestasi belajar siswa (p=0.03) antara dua sekolah tersebut. Kadar timbal serum berkorelasi negatif dengan prestasi akademik. Korelasi yang kuat ditemukan pada sekolah yang berjarak jauh dari jalan (r=-0.40). Disarankan kepada pemangku kepentingan terkait seperti pemerintah, industry, dan masyarakat untuk memberikan perhatian yang lebih banyak dalam usaha pencegahan pajanan timbal pada anak-anak.

Kata kunci : Pb, prestasi akademik, anak-anak, sekolah, jalan raya

Correspondence Address: Hasnawati Amqam , Department of Environmental Health, Faculty of Public Health, Universitas Hasanuddin. Makassar City, Indonesia hasnawati.amqam@unhas.ac.id

Received : October 23, 2022 Accepted : December 13, 2022 Published: December 20, 2022

Introduction

Lead (Pb) is a metal found in various materials and products, such as paint, soil, drinking water, food, cosmetics, gasoline, herbal products, and ceramics.[1,2] Lead exposure in humans can occur mainly through the respiratory tract, digestive tract, and dermal. For children, an important pathway is an oral route because of their habit of putting their hands in their mouths, and dust exposure is an important source in this pathway.[3] Children appear to absorb more water-soluble Pb through their gastrointestinal tracts than adults. Approximately 40–50% of ingested Pb is absorbed, according to estimates derived from dietary balance studies in children (up to 8 years of age).[4] The respiratory tract is also an important route of exposure for children because they spend a lot of time outdoors. They absorb more metals from the air due to higher respiratory (around 20 breaths/minute) and metabolic rates than adults (<10 breaths/minute).[5,6]

Lead is a toxic metal.[7,8] which contaminates the environment and can affect the central nervous system. According to the ATSDR, Pb is associated with decreased intelligence, impaired neurobehavioral development, impaired posture and growth, and hearing impairment. Children are susceptible to lead because the intake per unit of body weight is higher, and even at low levels can cause nerve damage. Exposure to Pb can interfere with cognitive development in children.[9,10]

Lead has no role in the body, so the detection of lead in the body is abnormal.[11] In 2012 the Centers for Disease Control and Prevention (CDC) set a reference value of 5 µg/dL for blood lead levels.[12,13] Exposure <5 µg/dL can cause effects on the nervous system in the form of cognitive function (decreased IQ, academic achievement, specific cognitive measures) and behaviour (attention and attention-related problems). Exposure to 10 g/dL, in addition to these effects, has an impact on the nervous system, namely auditory function (hearing loss), and on development and reproduction (growth disorders and delayed puberty).[14] Then in 2021, CDC have updated the reference value to 3.5 µg/dL based on National Health and Nutrition Examination Survey (NHANES) data from the 2015-2016 and 2017-2018.[15]

There are some exposure factors to the increase of blood lead levels in children. One of the factors is living in traffic-heavy urban areas, school locations on the heavy traffic road, and types of vehicles used for school.[16] With the rise in living standards, traffic has continued to rise. Multiple environmental issues are caused by heavy-duty diesel transport vehicles, which increase both exhaust emissions and the amount of dust raised by vehicles.[7] The relationship between traffic density and air Lead concentration is demonstrated by the correlation between the highest vehicle density and air Lead concentration.[17] The lead concentration was 0.0122 µg /m3 when the traffic reached 85 units/minute. Numerous studies have evaluated the effects of traffic on pollutant concentrations and investigated the impact of pollution on human health. For instance, traffic-

related pollution has negatively affected the human respiratory system.[8] Children are more exposed to Pb from the environment if they live near roads with high traffic density.[11,12] Although many locations are affected by traffic-related pollution, schools are disproportionately impacted due to the large number of vehicles that pass them daily. Vehicles parked at the school entrance increase the number of contaminants exposed to students.[18]

Leaded gasoline was banned in Indonesia in July 2006, and the ambient air's lead content started declining in September 2006. Six years following the implementation of the unleaded gasoline program, lead concentrations in PM2.5 were reduced. The average lead concentrations in PM2.5 since 2005 continually decreased year by year from 44.53 to 12.69 ng·m−3 in 2012.[19] However, although leaded gasoline has been eliminated, the Pb concentration was not directly eliminated in the air. A study in 2018 of Pb concentration in Lichens, a bioindicator of air pollution, showed a positive correlation between the traffic density with Pb concentration on the Lichens thallus.[20] Other studies also showed that Pb was still detected in urban air in some cities in Indonesia, including Makassar in 2019 (mean of 0.0297 µg/m3[21] and 2020.[22]

In Indonesia, there are already some studies observing Pb concentration in children. However, there are still rare studies comparing the exposure according to the distance of the school from the road as an exposure source and associated with academic performance. Makassar is one of Indonesia's big cities, with high-density traffic on some main roads. Some schools are located on the side of those roads. This study aims to analyze the relationship between Serum Lead Levels (SLL) and academic achievement of elementary school children.

Methods

The study is cross-sectional. It was conducted in August 2022. The study population was the 5th and 6th-grades students of Bawakaraeng I and Baraya I Elementary School in Makassar City. These Schools represent the location based on the distance from the road. The sample was selected through systematic random sampling from the students' list after obtaining written informed consent from their parents. There were 30 and 24 students from Bawakaraeng and Baraya Elementary School, respectively.

As much as 3 ml of venous blood was drawn from the children and brought to the laboratory. The student-level academic achievement was assessed from learning reports in five subjects; Mathematics, Indonesian, Science, Social Studies, and English. It is in mean of the five subjects and represented by numeric variables range from 0 to 100, which 100 is the highest score. SLL was analyzed using ICP (Inductively Coupled Plasma). Preparation: 1 mL of the blood sample was put in a nesler tube. 5-10 ml of Nitric Acid HNO3 was added to the tube. The tube was heated over a water bath at a temperature of 95o until the sample evaporated and looked clear, then filtered and diluted with 50 ml of distilled water.

Sample analysis: The calibration solution was taken from a standard lead solution with a concentration of 1000 g/lt and then diluted in a volumetric flask of different concentrations as in the standard lead solution. The solution was examined by ICP with a wavelength of 283.3 nm. The data of SLL and sores of the five subjects were not normally distributed. Hence we use the Mann-Whitney U test to perform the mean difference of those data between the schools nearby and distant from the road. We use the Spearman-Rho test to perform the correlation between lead concentration and academic performance. This study has obtained ethical clearance from the Ethics Commission of the Faculty of Public Health, Hasanuddin University, with Document No. 9677/UN4.14.1/TP.01.02/2022.

Results

Student Characteristic

In the school on the road side, the student sample was dominated by boys (56.7%) while in another school, it was dominated by girls (58.3%). Most of the students are in grade 5^{th}. The characteristics of this study subjets are presented in Table 1.

Table 1. Characteristics of Students in Two Schools in Makassar City

Characteristic	School Location			
	Road Side (N=30)		Distant from Road (N=24)	
	N	%	n	%
Sex				
Boys	17	56.7	10	41.7
Girls	13	43.3	14	58.3
Grade				
5^{th}	26	86.7	19	79.1
6^{th}	4	13.3	5	20.8

Serum Lead Level and Student Achievement

SLL and academic achievement are presented in Table 2. All students were exposed to lead. There was no significant difference in SLL between students who attended schools located on the side of the road and those located some distance away (p=0.43). However, the median (interquartile) SLL were higher (1.04 (0.52) µg/dL) in students from school at road side than in another school's students (0.88 (0.98) µg/dL). The minimum and maximum SLL were higher in students from Schools located distant from the main road.

Overall, the academic performance of the students in both of schools were good with the range of 87.90 to 92.20 in the school located on the road side. It is slightly higher than it in the school far from the road. A significant mean difference found between the two school in academic performance ($p<0.05$).

Table 2 Serum Lead Level and Students' Academic Achievement According to Distance of School to Road

Variable	Nearby Road		Distant from Road		
	Min-Max	Median (IQR)	Min-Max	Median (IQR)	*P-Value**
SLL (µg/dL)	0.39 – 5.97	1.04 (0.52)	0.42-6.44	0.88 (0.98)	0.43
Academic Performance	87.90 – 92.20	89.20 (1.23)	82.60 – 92.30	88.08 (3.56)	0.03**

***** Mann-Whitney U Test **p-value significant <0.05, sig (2-tailed)

Correlation of Serum Lead Levels to Children's Academic Achievement

From the Spearman-rho test, a significant negative correlation was seen in the association of SLL and students' academic performance (r =-0.234, *p*=0.044), as presented in Figure 1. Because no significant difference was found in SLL between the two schools, we analyzed the correlation in all students without grouping the schools.

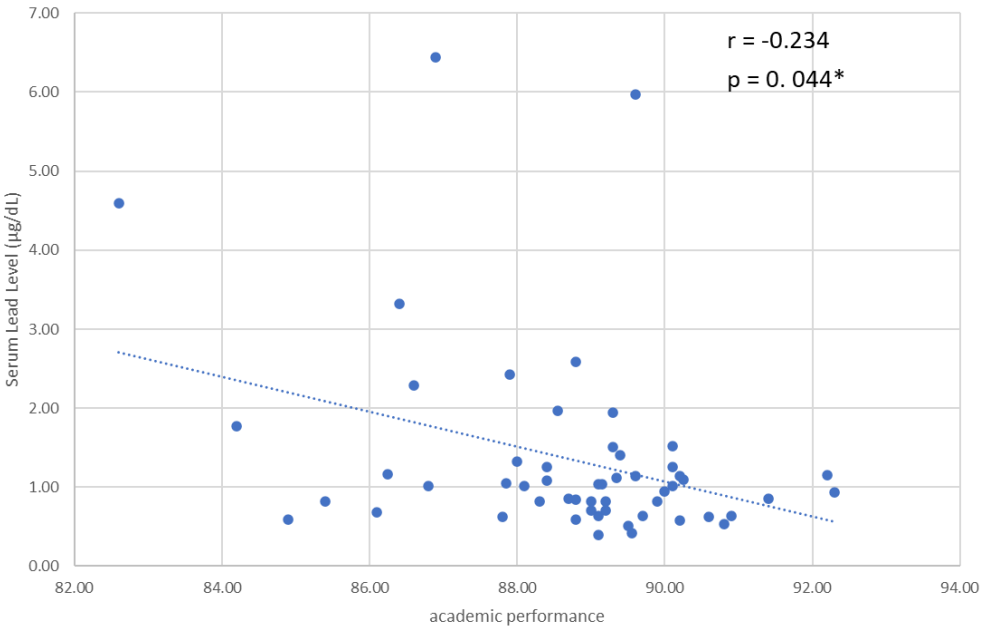

Figure 1. Correlation between SLL and Academic Achievement of Children. *Spearman-rho Test, one-tailed, significant if p<0.05

Discussion

In the current study, we measure the Pb concentration in serum. Metabolomics is a highly effective method for identifying the biological effects of Pb exposure. Assessing metabolites in biological matrices, such as plasma or serum, provides a picture of metabolic function, allowing for the investigation of biological responses to Pb exposure. In contrast to other 'omic techniques (e.g., genomics, transcriptomics, etc.), metabolomics reveals the actual condition of metabolic functioning. By examining metabolites and pathways associated significantly with Pb exposure, metabolomics can therefore indicate the metabolic links between Lead exposure and subsequent

health outcomes.[23]

Some studies indicate that Pb exposure causes biologically significant metabolic changes.[23] In observational studies, Pb can be measured in various samples, such as nails, hair, blood, urine and bone, with each matrix capturing a distinct exposure window. Bone and blood, the gold standards for Pb measurement, capture short-term and long-term exposure, respectively. The half-life of Pb is between one week and two months in blood, according to age and exposure history, and between 5 and 20 years in bone.[4] Prior metabolomics studies measured Pb primarily in the blood, which reflects relatively recent Pb exposure. Metabolomic assessments of bone Pb will add vital information to the scientific literature regarding the biological effects of prolonged Pb exposure.[23]

We measured the Pb concentrations of children attending primary school and distinguished between those whose schools were close to the road and those whose schools were far (500 m) from the road. This current study suggests that the maximum SLL was 6.44 µg/dL. However, insignificant SLL mean difference was discovered between the two school. The lead concentration was much lower than the previous study finding in elementary students from the school located close to the high traffic density road in Yogyakarta. The blood Lead concentration was 7-128.5 µg/dL.[17]

The Pb exposure for children who spend much time near the road area might come from traffic because automobile traffic density is correlated with lead concentration gradients in the atmosphere, soil, and people. A previous study observed that more than 57% of children living within 30.48 m of a major roadway and 68% of children living in interstitial areas (i.e., more than 60.96 meters from a major roadway) had blood-lead concentrations of 40 ug/dL or higher.[6] High concentrations of lead particles in dust and soil correlate with traffic density.[24] Another study showed that Children living on residential streets showed much lower blood lead concentrations than those living on wide streets or near a major road.[25] This result in the recent study might be because even though the second school is far from the road (500m), the shuttle vehicles still come in and out to the school location. Furthermore, Pb exposure not only comes from the road but may come from other sources.

The Pb concentration in this study is much lower than in other studies.[17,26] but Pb has no biological function; hence the presence of lead in the body is abnormal.[11] Although the CDC set a reference value of 3.5 µg/dL for blood lead levels, it can not be interpreted as "a safe level because it is not yet discovered yet.[27] The CDC establishes a reference value, not for a safe level but only to refer to children with greater blood lead levels than most children. Moreover, indisputable scientific evidence that the presence of below 5 µg/dL related to a cognitive function includes a decrease in academic achievement.[28]

This study observed a significant difference in academic performance between the students from school located near the main road and those from the school far (500 m) from the the main road. The proximity of schools to roadways is associated with student academic achievement is line with the finding that local traffic near schools (250 m buffer) had a greater impact on student performance than traffic far away (1 km buffer).[29] Prior researches also showed the proximity of schools to near roadways as a significant factor affecting schools' outdoor and indoor air quality.[30–32] Difference with the current finding, a study in Baltimore observed that the distance of school buildings to 'all roads' and 'major roads and roads were not significant to students' academic performance.[33]

We observed serum Pb concentration correlates with student-level academic performance in five subjects negatively. This finding is in line with a finding demonstrated a relationship between lead exposure and cognitive and behavioural impairment. However, in that study, the impairment occurred at significantly higher blood lead levels (9.02 to 27.36 μg/dl).[26] The impairment also might occur as the consequence of early exposure, as suggested in another study showing that poor academic performance in elementary and junior high school was substantially correlated with high blood lead levels before the age of six.[34]

In children, slight increases in blood lead concentrations (< 5 μg/dL) can negatively affect cognitive functions like IQ and school performance. At low blood lead concentrations, lead-associated IQ decrements are proportionately larger. The IQ decrease associated with an increase in blood lead content from <1 - 30 μg/dL was 9.2 IQ points, but the decrease from <1 to 10 μg/dL was 6.2.[35]

Lead has a significant impact on the intelligence of the general population. In US, even though blood lead levels have been eliminated down over the years, it is assumed that lead poisoning has induced a loss of 23 million IQ points among a 6-year group of children. Focusing on children with blood lead concentrations ≥5 μg/dL is efficient but will not save most children's IQ points. Reducing exposures for children with BLL ≥5 μg/dL will fail to preserve most children with lower lead exposure. Low blood lead levels presently have no effective treatments, therefore, avoiding exposure is the most important step. For these reasons, the emphasis of this statement is primarily on the role of physicians in preventing lead exposure in children.[35]

Finding and removing the main sources of lead exposure is essential to preventing lead poisoning in children. Contras to the main prevention approach, procedures and regulations have too often relied primarily on detecting lead exposure only when children acquire elevated blood lead concentrations.[35,36] Because low-level lead toxicity has irreversible effects, it is now widely acknowledged that primary prevention of lead exposure is the most effective approach.[35] CDC has developed lead contamination prevention programmes,[37] such as developing strategies and policies to reduce lead poisoning in children and educating the public and health care professionals about

mitigating childhood lead poisoning. Another programme is health surveillance of children for elevated blood lead levels and ensuring that children with elevated blood lead levels receive the necessary medical and environmental follow-up. In addition, establishing population-based measures to prevent childhood lead poisoning and conducting studies to determine the effectiveness of these strategies. This study has some limitations. Blood lead concentration can be influenced by air quality and various sources not measured in this study. So, it is suggested that the next studies consider those variables when measuring the lead level in children.

Conclusion

This study observed that lead was detected in all students' subjects. However, there is no significant difference in serum lead level of student-level academic performance between schools located on the road and far from the road (500 m). Furthermore, serum lead levels were correlated with academic performance negatively in the school far from the road, with a strong correlation in some subjects. It is suggested that although the current level of lead concentration in the students is relatively lower than in other studies, more attention is necessary to prevent lead exposure in children. Some actions were suggested: (1) designing strategies and policies to reduce lead poisoning in children, (2) informing the public and health care professionals on the prevention of childhood lead poisoning, (3) screening children for blood lead levels and ensuring that children with elevated blood lead levels receive the required medical and environmental follow-up. Moreover, developing population-based strategies to reduce childhood lead poisoning and researching to establish these strategies' efficacy.

Acknowledgement

This study was performed under the finance of the Institute for Research and Community Service Hasanuddin University. Hence the acknowledgement is the address for the research funding.

Funding

This research was conducted using funding from Institute for Research and Community Service Hasanuddin University under contract number 1476/UN4.22/PT.01.03.2022.

Conflict of Interest

The authors declare that there is no conflict of interest in this study.

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