Short Communication

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Blood lead levels and their association with children's factors, nutritional status, and daily dietary intake in used lead-acid battery (ULAB) recycling area

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Abstract

Evidence has shown that unregulated lead battery recycling is a significant contributor to lead exposure in many countries. The aim of this study was to investigate the factors associated with blood lead levels (BLLs) among children aged 1 to 5 who reside within 250 meters of used lead-acid battery recycling areas in three metropolitan neighborhoods in Indonesia. Using a cross-sectional approach, data was collected through in-person household visitations. The assessed risk factors included socio-demographic data, nutritional status, immunization, breastfeeding status, and daily food intake. BLLs were measured using the LeadCare II portable device and confirmed with plasma mass spectrometry, then classified based on the recommendations of the Centers for Disease Control and Prevention (CDC). A multivariate multinomial logistic regression was used to analyze the association between children's characteristics and daily eating habits as predictors of BLLs. Out of a total of 433 eligible children, 361 were included in this study. High monthly household income (adjusted odds ratio (aOR): 0.16; 95% confidence interval (95%CI): 0.04–0.67), child's age (aOR: 0.21; 95%CI: 0.07–0.64), and being boy (aOR: 2.19; 95%CI: 1.17–4.10) were associated with medium BLLs in comparison to low BLLs. In addition, high fruit consumption (AOR: 1.91; 95%CI: 0.99–3.66) and high dairy consumption (aOR: 0.42; 95%CI: 0.27–0.76) were associated with medium BLLs in comparison to low BLLs. Our study also indicated that being a boy (aOR: 5.53; 95%CI: 1.68–18.25), completed breastfeeding history (aOR: 3.47; 95%CI: 1.18–10.23), short outdoor activity duration (aOR: 0.30; 95%CI: 0.09–0.97), high heme-rich iron consumption (aOR: 0.32; 95%CI: 0.10–1.00), and high dairy consumption (aOR: 0.13; 95%CI: 0.04–0.44) were associated with high BLLs in comparison to low BLLs. This study highlights the necessity for further investigation into the impact of various dietary groups on the BLLs of children living around used lead-acid battery recycling areas.

Keywords: Environmental exposure, recycling area, lead-acid battery, blood lead level, nutritional status

Introduction

The presence of lead in home surroundings continues to be a notable concern for public health, especially for children. Globally, approximately 800 million children in 2020 had blood lead levels (BLLs) at or exceeding 5 µg/dL [1]. This number is a grave concern if linked to the effects of lead exposure, even at minimal BLLs, including neurological disorders (that result in delays in physical and mental development, learning difficulties, and reduced intellectual ability) [2-4],

Received: January 6, 2025 - Accepted: March 7, 2025 - Published online: March 11, 2025

psychomotor disorder [4], and indigestion (such as constipation dan chronic abdominal pain) [5-8]. A study discovered that elevated BLLs in Zambia's children also significantly and adversely affected the mental health of the child's mother [9].

Several comprehensive analyses have determined that the primary causes of lead exposure are unregulated recycling and production of lead-acid batteries, mining and metal processing, electronic waste, and the utilization of lead as a food contaminant, particularly in spices [2,10-13]. There is little doubt that environmental exposure is a major contributing cause to the rise in BLLs. A study discovered that children residing within a 200-meter radius of a lead smelting facility in Kenya had a higher probability of having BLLs equal to or exceeding 5 μg/dL in comparison to children residing at a distance of 200 meters or more from the facility [14]. Furthermore, another study emphasized the significance of lead exposure intensity in the environment, particularly in connection with the used lead-acid battery (ULAB) recycling industry, as well as the proximity to the source of exposure [15]. Therefore, the locations where youngsters spend their time playing and engaging in activities become increasingly important [15-18]. Other studies identified additional risk factors strongly linked to elevated BLLs in children. These factors include the release of lead from deteriorating paint or pipes in older homes where economically disadvantaged families reside [19-21], the consumption of contaminated tap water by breastfeeding mothers [21-23], the body mass index (BMI) of children relative to their age [24], the frequency of outdoor activities among children [25], and urbanization [26].

Notably, in addition to exposure, children's BLLs are affected by their food. A study conducted in Benin found that there was a significant correlation between the consumption of wild animals killed by lead bullets, the consumption of peanuts more than once a month, and increased BLLs in 6-year-old children [27]. Nevertheless, this study solely classified the intake of specific food categories, including tubers, legumes, grains, and potatoes [27]. We hypothesize that the nutritional composition of meals, including protein, fat, carbohydrates, and other components, may have an impact on the BLLs of children who have been exposed to lead. Hence, the aim of this study was to identify the factors that impact the levels of lead in the bloodstream of children, together with their dietary patterns and intake of essential nutrients.

Methods

Study design, study area, and study participants

Data collection was conducted in April 2015 using a cross-sectional design in three specific neighborhoods (subdistricts) situated in DKI Jakarta Province (Pegangsaan Dua Subdistrict) and Banten Province (Cipondoh Subdistrict and Dadap Subditrict), Indonesia, where ULAB recycling takes place [25].

This study involved children aged between 1 and 5 years who resided within a distance of 0 to 250 meters from the ULAB recycling site. The children were chosen using a simple random sampling method using data provided by the local healthcare post (known as *Posyandu* in Indonesia). A total of 361 out of 433 eligible children were selected to take part in this study. Among them, 187 resided within a distance of less than 200 meters (near group) from the ULAB recycling site, while the remaining 174 lived between 200 and 250 meters (far group) from ULAB recycling site.

Data collection

The listing of the children's names was obtained from the *Posyandu* and randomly selected from the list. Data collection was conducted through face-to-face interviews with the parents (father or mother) or caregivers of the children, carried out by the data collection team at the residences of the selected children. Upon conclusion of the interview, a phlebotomist, accompanied by a physician, performed blood sampling.

Blood sampling was conducted following a standardized protocol, which commenced with cleansing the child's arm with soap and water, followed by drying with a chemical-free tissue, then disinfecting with alcohol-soaked cotton, and finally drying again with sterile gauze. A total of 3 mL of venous blood was collected in a tube for analysis. The phlebotomist subsequently affixed an adhesive bandage to the puncture site. The LeadCare II portable blood lead testing

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device (Magellan Diagnostics, Cambridge, MA) was used to measure blood lead levels. To ensure quality assurance, 15% of the venous blood samples were randomly split and analyzed using inductively coupled plasma mass spectrometry with the NexION 300X (PerkinElmer, Shelton, Connecticut, USA), which was provided and analyzed by the Prodia Occupational Health Institute, Jakarta, Indonesia. We found a very strong correlation between lead levels received from LeadCare II portable device and mass spectrometry, with *r*=0.82.

Study variables

This study's dependent variable (outcome) was children's BLLs that were categorized into three groups: low (0 to 5 μg/dL), medium (6 to 9 μg/dL), and high (≥10 μg/dL), based on Central of Disease Control (CDC) guideline and recommendation for childhood lead poisoning prevention programs [28]. Several independent variables (possible risk factors that influence the BLLs) were measured in this study. The survey instrument utilized in this study comprised questions regarding socio-demographic data and factors pertaining to a child's exposure to lead. The variables considered in our analysis were as follows: the level of education of the mother or caregiver (primary education compared to secondary and higher education), the occupation of the mother or caregiver (employed compared to unemployed), the monthly income (less than or equal to 1 million Indonesian Rupiah (IDR), greater than 1 to 3 million IDR and >3 million IDR), the presence of a smoker in the household (no compared to yes), the distance to the ULAB recycling facility (200–250 meters compared to less than 200 meters), the age of the child (1, 2, 3, 4 and 5 years old), the sex of the child (boy compared to girl), and the birth weight of the child (<2500 grams compared to ≥2500 grams).

In addition, the nutritional status of the child was also assessed based on the World Health Organization (WHO) classification of nutritional status for children [29] to see the potential acute malnutrition based on weight-for-age, which was categorized into normal nutritional status compared to underweight (<-2 standard deviations (SD) of median). Chronic malnutrition was calculated based on height-for-age and classified into three categories: normal nutritional status, stunting (<-2 SD of median), and severe stunting (<-3 SD of median).

The immunization status of each child was also assessed. A child who received the primary vaccination between the ages of 12 and 59 months was classified as having complete primary vaccination, whereas those who did not receive at least one primary vaccination were classified as having incomplete vaccination [30]. For exclusive breastfeeding status, children were categorized into two groups: complete (a child exclusively breastfed for the initial six months of life without supplementary food or beverages) and incomplete (a child who was neither breastfed nor provided with supplementary food and beverages during the initial six months of life) [31]. The duration of the child's outdoor activity was categorized into two groups: less than five hours and five hours or more [25].

In addition, we incorporated a daily food intake variable using a food frequency questionnaire (FFQ), which was developed based on the Indonesian list of food composition [32] and previously validated by another study [33]. We also utilized food models and instruments to accurately measure food consumption [34-36]. The recall period included the previous four weeks, and the frequency options included never, daily, weekly, monthly, and never. The food items were categorized into five groups: heme-rich iron, non-heme-rich iron, root vegetables, fruits, and dairy products. The daily intake was determined by calculating the frequency of intake (conversion factor), serving size, total number of servings, and weight of food in one serving for each item [33]. The conversion factor for the given values was as follows: never=0, <1/month=0.02, 1–3/month=0.07, 1/week=0.14, 2–4/week=0.43, 5–6/week=0.79, 1/day=1.0, 2–3/day=2.5, and ≥4/day=4 [37]. Subsequently, the overall score of daily food consumption was segregated into two groups: low and high consumption, using the median cut-off point.

Statistical analysis

A multi-step logistic regression analysis was used to evaluate the relationship between independent variables and BLLs. Initially, all independent factors were incorporated into a univariate logistic regression analysis to determine the crude odds ratio (OR). Subsequently, the multivariate analysis incorporated independent variables that exhibited a *p*-value of ≤0.25 in the univariate study. A multinomial logistic regression analysis was conducted to examine the relationship between independent variables and BLLs by measuring the adjusted odds ratios (aOR) with a 95% confidence interval (95%CI) for each variable. The multivariate analysis was conducted with a significance level set at $p<0.05$. The analysis was performed using SPSS version 20 (IBM, New York, USA).

Results

Characteristics of participants

Out of 361 eligible children, 42 parents from the near group and 30 from the far group of ULAB recycling sites declined to participate in the study, resulting in a refusal rate of 22.1%. Eight fathers specifically refused to allow their children's blood to be drawn. No data on occupation or other potential risk factors for lead exposure were collected from families who declined participation. Additionally, two children moved away before the study commenced.

A total of 279 children were included and analyzed in the study: 92 from Pegangsaan Dua, 92 from Cipondoh, and 95 from Dadap. The socio-demographic characteristics of the parents are presented in **Table 1**. Only five respondents (1.8%) had graduated from university, while the majority, 238 (85.3%), were unemployed. Furthermore, a significant proportion of children, 209 (74.9%), were exposed to household smoking (**Table 1**). Most of the children were born with a normal birth weight of at least 2,500 grams (**Table 1**). However, 187 children (67.0%) were underweight, 51 (18.3%) were stunted, and 38 (13.6%) were severely stunted. Additionally, a large proportion of children, 172 (61.6%), did not receive exclusive breastfeeding for the recommended duration of six months (**Table 1**).

Table 1. Characteristics of socio-demographic factors of parents and children included in the study (n=279)

Group	Variable	Blood lead level category			Total
		Low (n=147)	Medium (n=106)	High (n=26)	
		n (%)	n (%)	n (%)	
Parent	Education of respondent				
	Primary	87 (59.2)	70 (66.0)	19 (73.1)	176
	Secondary	55 (37.1)	36 (34.0)	7 (26.9)	98
	Higher	5 (3.4)	0 (0.0)	0 (0.0)	5
	Occupation of respondent				
	Employed	27 (18.4)	11 (10.4)	3 (11.5)	41
	Unemployed	120 (81.6)	95 (89.6)	23 (88.5)	238
	Monthly income (in IDR)				
	>3 million	49 (33.3)	22 (20.8)	7 (26.9)	78
	>1 to 3 million	92 (62.6)	70 (66.0)	15 (57.7)	177
	≤1 million	4 (2.7)	12 (11.3)	3 (11.5)	19
	Missing data	2 (1.4)	2 (1.9)	1 (3.9)	5
	Smoking person in household				
	No	38 (25.8)	24 (22.6)	6 (23.1)	68
	Yes	107 (72.8)	82 (77.4)	20 (76.9)	209
	Missing data	2 (1.4)	0 (0.0)	0 (0.0)	2
	Distance to ULAB recycling (meters)				
	Distant (200 to 250)	72 (49.0)	53 (50.0)	16 (61.5)	141
	Near (<200)	75 (51.0)	53 (50.0)	10 (38.5)	138
Children	Age (years old)				
	1	40 (27.2)	16 (15.1)	6 (23.1)	62
	2	37 (25.2)	27 (25.5)	5 (19.2)	69
	3	27 (18.4)	16 (15.1)	7 (26.9)	50
	4	26 (17.7)	24 (22.6)	5 (19.2)	55
	5	17 (11.6)	23 (21.7)	3 (11.5)	43
	Sex				
	Boy	74 (50.3)	68 (64.2)	20 (76.9)	162
	Girl	73 (49.7)	38 (35.8)	6 (23.1)	117
	Birth weight (gram)				
	≥2500	134 (91.1)	101 (95.3)	25 (96.2)	260
	<2500	11 (7.5)	5 (4.7)	1 (3.8)	17
	Missing data	2 (1.4)	6 (5.7)	0 (0.0)	2
	Nutritional status (weight-for-age)				
	Underweight	106 (72.1)	64 (60.4)	17 (65.4)	187

Group	Variable	Blood lead level category			Total
		Low (n=147)	Medium (n=106)	High (n=26)	
		n (%)	n (%)	n (%)	
	Normal	35 (23.8)	36 (33.9)	9 (34.6)	80
	Overweight	6 (4.1)	6 (5.7)	0 (0.0)	12
	Nutritional status (length/height-for-age)				
	Normal	97 (66.0)	77 (72.6)	16 (61.5)	190
	Stunting	29 (19.7)	15 (14.2)	7 (26.9)	51
	Severe stunting	21 (14.3)	14 (13.2)	3 (11.5)	38
	Immunization history				
	Complete	127 (86.4)	90 (84.9)	22 (84.6)	239
	Incomplete	18 (12.2)	16 (15.1)	4 (15.4)	38
	Uncountable*	2 (1.4)	0 (0.0)	0 (0.0)	2
	Exclusive breastfeeding history				
	Complete	51 (34.7)	40 (37.7)	14 (53.8)	105
	Incomplete	95 (64.6)	65 (61.3)	12 (46.2)	172
	Uncountable*	1 (0.7)	1 (1.0)	0 (0.0)	2
	Duration of child's outdoor activities (hours)				
	<2	46 (31.3)	26 (24.5)	3 (11.5)	75
	2–4	68 (46.3)	53 (50.0)	10 (38.5)	131
	5–6	27 (18.4)	14 (13.2)	9 (34.6)	50
	≥7	6 (4.1)	13 (12.3)	4 (15.4)	23

ULAB: used lead-acid battery
*Child's age less than six months for breastfeeding and less than one year for immunization

Children's food consumption

The most frequently consumed food among children was dairy products, with an average daily intake of 157.5 grams per day (SD±152.0 grams/day). In contrast, root vegetables and fruits were found to be the least popular food choices, with mean daily consumption of 4.29 grams for root vegetables and 4.68 grams for fruits (**Table 2**).

Table 2. Average food consumption by children included in the study in gram/day

Food group	Mean±SD	Median (IQR)
Heme-rich iron	6.75±11.93	1.59 (0.37–6.78)
Non-heme-rich iron	6.16±18.60	0.42 (0.00–3.39)
Root vegetable	4.29±9.95	0.77 (0.09–4.24)
Fruits	4.68±16.99	0.21 (0.00–1.84)
Dairy product	157.45±152.04	131.68 (22.90–233.59)

The consumption of each food group by children, categorized according to their BLLs, is presented in **Figure 1**. This study found that children with medium and high BLLs had a lower frequency of dairy product consumption.

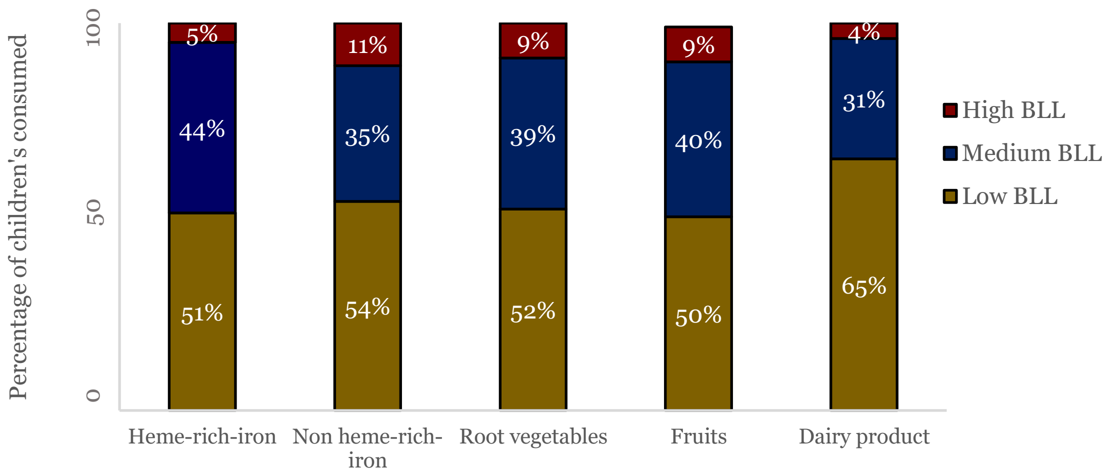

Figure 1. Mean proportion of children who consumed each food group per day by blood lead level (BLL) (n=279).

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Factors associated with children's blood lead levels (BLLs)

The multivariable analyses identified eight characteristics that were associated with the BLLs of children, including monthly income, the child's age and sex, breast-feeding history, length of outdoor exercise, intake of heme-rich iron, consumption of fruits, and consumption of dairy products (**Table 3**). Children living in households with the highest monthly income group (>3 million Rupiah) had an 84.0% lower likelihood of having medium BLLs compared to low BLLs, in comparison to those living in households with the lowest monthly income (<1 million Rupiah) (**Table 3**).

Children who were one year old had a 79.0% reduced likelihood of having medium BLLs compared to low BLLs, in comparison to children who were five years old. Boys showed a greater likelihood of having medium (aOR: 2.19; 95%CI: 1.17–4.10) and high BLLs (aOR: 5.53; 95%CI: 1.68–18.25) compared to girls, as opposed to having low BLLs. Curiously, children who were exclusively breastfed had about three and a half times greater likelihood (aOR: 3.47; 95%CI: 1.18–10.23) of having high BLLs compared to those with low BLLs. Furthermore, the likelihood of having high BLLs, as opposed to low BLLs, was reduced by 70.0% among children who spent less than five hours engaged in outdoor activities compared to those who spent five hours or more (**Table 3**).

In relation to a child's daily intake, children who ingested a high amount of heme-rich iron per day had a lower likelihood (aOR: 0.32; 95%CI: 0.10–1.00) of having high BLLs compared to those who consumed a low amount of heme-rich iron per day (**Table 3**). On the other hand, children who ate a large amount of fruit per day had nearly double the likelihood (aOR: 1.91; 95%CI: 0.99–3.66) of having moderate BLLs, as opposed to low BLLs, compared to those who consumed a small amount of fruit per day. Children who consumed a high amount of dairy products per day had a 58.0% lower chance of having medium BLLs and an 87.0% lower chance of having high BLLs compared to those who consumed a low amount of dairy products.

Table 3. Multivariate analysis using multinomial logistic regression showing the factors associated with the levels of blood lead in children

Variable	Medium vs low blood lead level	High vs low blood lead level
	Adjusted OR (95%CI)	Adjusted OR (95%CI)
Education (reference (*ref*): secondary and higher)		
Primary	1.23 (0.64–2.37)	1.62 (0.49–5.36)
Occupation (*ref*: unemployed)		
Employed	0.48 (0.19–1.21)	0.85 (0.19–3.85)
Monthly income (*ref*: ≤1 million)		
>1 to 3 million	0.28 (0.08–1.03)	0.18 (0.03–1.30)
>3 million	0.16 (0.04–0.67)*	0.24 (0.03–2.11)
Smoking person in household (*ref*: yes)		
No	0.74 (0.36–1.50)	0.89 (0.25–3.22)
Distance to ULAB recycling (*ref*: near)		
Distant	0.91 (0.50–1.66)	1.45 (0.51–4.13)
Child's age (*ref*: 5 years old)		
1	0.21 (0.07–0.64)**	1.22 (0.18–8.53)
2	0.39 (0.15–1.07)	0.80 (0.12–5.31)
3	0.36 (0.12–1.08)	3.07 (0.45–21.18)
4	0.81 (0.29–2.26)	1.78 (0.26–12.30)
Child's sex (*ref*: girl)		
Boy	2.19 (1.17–4.10)*	5.53 (1.68–18.25)*
Birth weight (*ref*: <2500 gr)		
≥2500	2.49 (0.64–9.68)	3.56 (0.25–50.10)
Nutritional status (*ref*: underweight)		
Normal	1.97 (0.99–3.84)	2.55 (0.78–8.30)
Nutritional status (*ref*: severe stunting)		
Normal	1.38 (0.59–3.23)	1.00 (0.22–4.55)
Stunting	0.77 (0.26–2.23)	1.28 (0.21–7.62)
Immunization history (*ref*: incomplete)		
Complete	0.84 (0.35–2.02)	1.23 (0.26–5.80)
Exclusive breastfeeding history (*ref*: incomplete)		
Complete	1.37 (0.72–2.61)	3.47 (1.18–10.23)*
Duration of child's outdoor activities (*ref*: ≥5 hours)		
<5 hours	1.23 (0.59–2.57)	0.30 (0.09–0.97)*

Variable	Medium vs low blood lead level	High vs low blood lead level
	Adjusted OR (95%CI)	Adjusted OR (95%CI)
Heme-rich iron (*ref*: low)		
High	1.24 (0.68–2.27)	0.32 (0.10–1.00)*
Non-heme-rich iron (*ref*: low)		
High	0.94 (0.51–1.76)	1.62 (0.56–4.73)
Root vegetable (*ref*: low)		
High	1.09 (0.58–2.05)	1.18 (0.39–3.58)
Fruits (*ref*: low)		
High	1.91 (0.99–3.66)*	1.08 (0.36–3.26)
Dairy product (*ref*: low)		
High	0.42 (0.27–0.76)*	0.13 (0.04–0.44)***

ULAB: used lead-acid battery
*Statistically significant at $p<0.05$
**Statistically significant at $p<0.01$
***Statistically significant at $p<0.001$

Discussion

This study examined predictor variables that were associated with BLLs in children living near to ULAB recycling areas in three metropolitan neighborhoods in Indonesia. We have identified several factors that were associated with BLLs, including the monthly income of the household, the child's age, the child's sex, breastfeeding status, and the duration of the child's outdoor activity. Additionally, we have found that three food groups, namely heme-rich iron, fruits, and dairy products, are also associated with BLLs.

Our study revealed a correlation between the economic position of a household and the BLLs in children. In particular, we found a negative association between higher monthly income and higher BLLs in children. This outcome is consistent with previous research conducted in both developing and developed countries [27,38-40]. Based on a five-year national dataset, a study conducted in the USA discovered a correlation between race/ethnicity and BLLs, of which non-Hispanic black children from low-income households consistently had higher BLLs compared to white children [38]. Another study that was also conducted in the USA asserted that living in impoverished conditions significantly increased the risk of children being exposed to lead through the ingestion of paint [40]. Monthly income is closely linked to poverty, low education, and bad health conditions [39].

Children's age is a reliable indicator of BLLs in the ULAB region, as demonstrated by the present study. This study indicated that the likelihood of having a medium level of BLLs, as opposed to a low BLLs, was reduced by 79.0% in children who were one year old compared to those who were five years old. The clear and logical explanation is that older children were more vulnerable to lead exposure because of their increased outdoor activities, which exposed them to dust containing lead. A study conducted in 2019 discovered a parallel observation: children under the age of two who engaged in outdoor activity had twice the likelihood of having elevated BLLs compared to children who exclusively played indoors at home [41]. Previous investigations have provided evidence to support this finding [42,43]. In contrast, a study among new migrant children in Greece found that younger children were more likely to have increased BLL compared to schooled children due to hand-to-mouth behavior [44]. However, this study defined a younger child with age range 1 to 5 years old (preschool children) [44].

Our findings indicated that boys had a greater likelihood of having elevated BLLs in comparison to girls. Previous research has yielded conflicting results regarding the association in question [27,41,42]. Previous study [42] asserted that boys were more likely to be exposed to lead from air, food, water, and dust due to their higher engagement in outdoor activities compared to girls. On the contrary, other studies did not find a correlation between the sex of a child and their BLLs [27,41].

Another predictor that influenced the BLLs in children was breastfeeding status. This study indicated a negative association between full breastfeeding in children and increased BLLs. One potential explanation is that lead exposure is passed from a woman with a high BLLs to her children through breastfeeding. While certain studies have reported comparable findings [22,23,45], a study discovered that blood lead exposure negatively correlated with serum prolactin levels in lactating mothers during lactation in Indonesia [23]. However, further research is required to evaluate the relationship between breastfeeding status and BLLs in children.

Although previous research has shown a correlation between a child's nutritional status and their BLLs [46,47], our study did not yield similar findings. This could potentially indicate variations in the frequency of lead exposure within a particular community. For instance, residing in a consistently contaminated immigrant area with high levels of lead exposure [3] or living in a mining region [46], may contribute to increased lead exposure, even at low concentrations. Our study also found that a high intake of heme-rich iron and dairy products was associated with a protective effect on BLLs. Conversely, children who consumed a high amount of fruits per day had nearly twice the BLLs compared to those who consumed a low amount of fruits per day. This is a realistic statement because the absorption of lead in our body is influenced by various factors, including the existence of dietary components, such as iron status, as well as the solubility of lead [48]. Nevertheless, the relationship between the daily consumption of fruit and the level of lead in the blood of children remains a subject of debate in certain previous studies [27,48,49]. A study conducted in Uruguay examining the impact of consuming group food containing heme and non-heme iron, vitamin C from fruits, and dairy products on lead biomarkers found no significant association between these dietary factors and changes in lead biomarkers [48]. Further investigations are needed to clarify whether these dietary groups are linked to BLLs in the general population.

To the best of our knowledge, this was the first study to consider daily intake as a predictive factor for BLLs among children in Indonesia. This study thoroughly examined the association between children's nutritional intake and their BLLs, referencing literature from various countries. However, this research has some limitations to consider. First, this study was conducted nearly a decade ago; however, the practice of ULAB persists, thereby endangering the surrounding community. Due to ULAB's noncompliance with current regulations and its illegal status, obtaining regular or periodic access for observation of exposure is challenging. Consequently, we assert that this 2015 data remains pertinent, particularly for evaluating the nutritional impacts of lead exposure. Secondly, the results of the study are limited to the subpopulation of the ULAB region in Jakarta, so the results may not be generalized to the general population and should be interpreted according to the population character of these three regions. Third, the limited sample size, particularly for the group of children with high BLLs, may diminish the reliability of the analysis for this group. Finally, the restriction of the reproducibility study should be a possible memory effect during the completion of the FFQ because respondents can still recall what the children ate four weeks ago and may be biased due to reduction or overestimation. Despite these constraints, the results of this research are considered significant to contribute to public health knowledge.

Conclusion

This study identified several characteristics that were correlated with children's current situation, including economic position, age and sex of the child, and the child's outdoor activities. These factors were found to be associated with BLLs. Our investigation revealed no correlation between nutritional status and BLLs in children in the ULAB area. However, we did find that the daily consumption of food groups rich in heme iron, fruits, and dairy products had an impact on a child's BLLs. Nevertheless, the reliability of the findings remains a subject of debate, and the explanation provided is not as obvious as in previous studies. Hence, conducting additional research with enhanced study methodology and a larger sample size could be advantageous in enhancing the outcomes.

Ethics approval

The Research and Community Engagement Ethical Committee is a part of the Faculty of Public Health of the University of Indonesia. Children whose BLLs are equal to or greater than 5 µg/dL were directed to the Health Care Unit for medical evaluation and subsequent blood lead testing. Prior to enrollment, all participants provided their signatures on written informed consent forms. The study was conducted in compliance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for research involving human subjects.

Acknowledgments

We thank the US Environment Protection Agency (EPA) for financial support and the US Centers for Disease Control and Prevention (CDC) for technical support of this study. We thank Mary Jean Brown (CDC) for technical support during this study. We thank Rakhi Kasat (EPA) for technical oversight of this study. We also thank Budi Susilorini of Blacksmith Institute and the Indonesian Lead Information Center (*Komite Penghapusan Bensin Bertimbel*) for their assistance in gaining entry into the community, and William Hawley (CDC) for comments on this manuscript. We also thank Donald Meadows (CDC) for his copy-editing assistance.

Competing interests

All the authors declare that there are no conflicts of interest. The conclusions, findings, and opinions expressed by authors contributing to this journal do not necessarily reflect the official position of the US CDC or the authors' affiliated institutions.

Funding

This study received funding from the US Environmental Protection Agency.

Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

Declaration of artificial intelligence use

This study used artificial intelligence (AI) tool for manuscript writing support. AI-based language model, Quillbot, was employed for language refinement (improving grammar, sentence structure, and readability of the manuscript). We confirm that all AI-assisted processes were critically reviewed by the authors to ensure the integrity and reliability of the results. The final decisions and interpretations presented in this article were solely made by the authors.

How to cite

Machmud PB, Prihartono I, Prihartono NA. Blood lead levels and their association with children's factors, nutritional status, and daily dietary intake in used lead-acid battery (ULAB) recycling area. Narra J 2025; 5 (1): e2059 - http://doi.org/10.52225/narra.v5i1.2059.

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