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Original Article

Investigation of blood lead levels in children with microcytic anemia and healthy children in Malatya and its surrounding areas

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ABSTRACT

Objective: This study aimed to investigate blood lead levels (BLLs) in children with microcytic anemia living in Malatya and its surrounding areas, to compare them with those of healthy children, and to evaluate the relationship between BLLs, microcytic anemia, and possible risk factors for lead exposure.

Materials and Methods: This study included 220 children aged 2-17 years between December 2018 and June 2019. Of these, 110 had microcytic anemia and 110 were healthy controls. BLLs were measured in all participants. A questionnaire was administered to assess potential risk factors for lead exposure, including plastic toy exposure, residence near a main road, parental or household occupational/hobby-related lead exposure, residence in a house built before 1950, and immigrant or refugee status.

Results: The median age of the participants was 8.0 years (interquartile range: 3.5-13.0). The mean BLL was 7.6±0.3 µg/dL, and all participants had BLLs above 5 µg/dL. All children had plastic toy exposure, and none lived in a house built before 1950. There was no significant difference in BLLs between children with microcytic anemia and healthy controls. BLLs were significantly higher in children whose parents or household members had occupational or hobby-related lead exposure than in those without such exposure ($p<0.001$). BLLs were also significantly higher in immigrant or refugee children than in non-immigrant and non-refugee children ($p<0.001$).

Conclusion: Children living in Malatya and its surrounding areas had BLLs above current reference values; however, BLLs were not associated with microcytic anemia. Higher BLLs among immigrant and refugee children and in children with household occupational or hobby-related exposure indicate the need for targeted screening and environmental source control. Preventing lead exposure is important to reduce long-term adverse health effects in children.

Keywords: Blood, child, lead, microcytic anemia, refugees

Introduction

Lead exposure remains a major and preventable environmental health problem in children. Current evidence indicates that there is no safe blood lead level (BLL) in childhood. The Centers for Disease Control and Prevention lowered the blood lead reference value from 5 µg/dL to 3.5 µg/dL in 2021 to identify children with higher exposure than most of their peers and to initiate appropriate public health actions (1,2). Even low-level lead exposure has been associated with adverse neurodevelopmental outcomes, including decreased intelligence, attention problems, behavioral difficulties, and learning impairment (2,3).

Children may be exposed to lead through contaminated household dust and soil, old lead-based paints, drinking water systems, industrial emissions, battery production and recycling, toys, jewelry, ceramic or metal cookware, imported spices, traditional cosmetics, and folk remedies (3,4). Young children are particularly vulnerable because of frequent hand-to-mouth behavior, higher gastrointestinal absorption, and the susceptibility of the developing nervous system to lead toxicity (3,5). Maternal lead exposure during pregnancy and lactation may also affect the fetus and infant through placental transfer and mobilization of lead from maternal bone stores (6).

Lead toxicity may affect multiple organ systems, including the nervous, hematologic, renal, cardiovascular, gastrointestinal, endocrine, and immune systems (3,7). Its hematologic effects are mainly related to impaired heme synthesis, disruption of porphyrin metabolism, reduced incorporation of iron into heme, and shortened erythrocyte survival (7,8). Therefore, lead poisoning is included in the differential diagnosis of microcytic anemia. However, the absence of anemia does not exclude lead exposure, since neurodevelopmental effects

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may occur at lower BLLs before hematologic abnormalities become apparent (3,8).

Iron deficiency and lead exposure are closely related. Because lead and iron may share common gastrointestinal transport pathways, iron deficiency can increase lead absorption. In addition, children with iron deficiency anemia may be more likely to have nutritional, socioeconomic, and environmental risk factors that increase lead exposure (8,9). Refugee and immigrant children may also be at increased risk because of pre-migration environmental exposures and post-migration factors such as crowded housing, poor nutrition, use of imported or traditional products, and limited access to preventive health services (10,11).

Previous data indicate that lead exposure has historically been an important public health concern in Malatya. A study conducted in 1998 reported a mean BLL of 21.8 µg/dL among children living in the city center and surrounding villages (12). However, contemporary regional data were lacking to demonstrate how childhood BLLs had changed following major changes in potential exposure sources, including the phase-out of leaded petrol. In addition, migration to the region following the Syrian conflict increased the need to evaluate lead exposure among refugee children, who may have distinct pre-migration and post-migration exposure risks. An updated regional assessment therefore provided an opportunity both to evaluate the change in BLLs among the local pediatric population and to compare BLLs between refugee and non-refugee children. This study aimed to compare BLLs between children with microcytic anemia and healthy children living in Malatya and its surrounding areas, to evaluate the relationship between BLL and hematologic parameters, and to identify possible risk factors associated with lead exposure, including immigrant or refugee status.

Materials and Methods

This prospective case-control study was conducted between December 2018 and June 2019. The study included children with microcytic anemia who were admitted to the pediatric hematology outpatient clinic of İnonü University Turgut Özal Medical Center, Malatya, Türkiye in eastern Türkiye and healthy children who were admitted to the general pediatric outpatient clinic for routine well-child examination.

The patient group consisted of 110 children aged 2–17 years with microcytic anemia. The control group consisted of 110 children in the same age range who were admitted to the general pediatric outpatient clinic for routine well-child examinations. Microcytic anemia was defined as hemoglobin and mean corpuscular volume values below the age-specific reference limits reported by Lanzkowsky, based on complete blood count findings (13). Children with known alternative causes of microcytosis or anemia, including thalassemia, thalassemia carrier status, hemoglobinopathies, and anemia of chronic disease, were excluded from the patient group. Hemoglobin electrophoresis was not routinely performed in all participants; however, children in whom thalassemia or thalassemia carrier status had been identified by hemoglobin electrophoresis during their clinical evaluation were not included in the study. Children were included in the control group only if no disease was identified through medical history or physical examination and all complete blood count parameters were within the age-specific reference ranges reported by Lanzkowsky (13). Children with any clinical or hematological abnormality were excluded from the control group.Complete blood count was performed using EDTA-anticoagulated blood samples with a Sysmex XN-1000 hematology analyzer (Sysmex Europe GmbH, Norderstedt, Germany). Blood samples were collected into two EDTA tubes and analyzed on the same day. For lead measurement, 2 mL of 20% trichloroacetic acid was added to 2 mL of blood obtained from the other EDTA tube, and the mixture was vortexed. It was then centrifuged at 5000 rpm for 30 minutes. After cell particles and proteins were precipitated, supernatant samples were obtained and stored at -80 °C until lead analysis. Blood lead levels were measured in triplicate using graphite furnace atomic absorption spectrometry with a Perkin Elmer AAnalyst 800 device (Perkin Elmer, USA).

A questionnaire was administered to the parents or caregivers to determine possible risk factors for lead exposure. The questionnaire included age, sex, plastic toy exposure, residence near a main road, parental occupational or hobby-related lead exposure, residence in or regular visits to a house built before 1950, and immigrant or refugee status.

Statistical Analysis

Statistical analyses were performed using SPSS version 22.0 (Statistical Package for Social Sciences; SPSS Inc., Chicago, IL, USA). Continuous variables were presented as mean and standard deviation or median and interquartile range, and categorical variables were presented as numbers and percentages. The chi-square test was used to compare categorical variables. Student's t test and the Mann-Whitney U test were used to compare continuous variables, as appropriate. A p value of <0.050 was considered statistically significant.

Results

The median age of all participants was 8.0 years (interquartile range: 3.5-13.0). Of the 220 participants, 81 (36.8%) were aged ≤5 years and 139 (63.2%) were older than 5 years.

Table I: Demographic and exposure-related characteristics of the study population

	n(%)
Age category	
≤5 years old	81 (36.8)
>5 years old	139 (63.2)
Sex	
Female	112 (50.9)
Male	108 (49.2)
Living in a house on the roadside	
Yes	95 (43.2)
No	125 (56.8)
Parents' work/hobby exposure	
Yes	111 (50.5)
No	109 (49.5)
Immigrant/refugee status	
Yes	23 (10.5)
No	197 (89.5)

Table II: Comparison of demographic and exposure-related characteristics between the anemia and control groups

	Control group (n=110)	Anemia group (n=110)	p
Age*	9.0 (5.0-13.0)	6.0 (3.0-12.0)	0.002
Age category†			
≤ 5 years old	31 (28.2)	50 (45.5)	0.008
>5 years old	79(71.8)	60 (54.5)	
Sex†			
Female	50 (45.5)	62 (56.4)	0.106
Male	60 (54.5)	48 (43.6)	
Living in a house on the roadside†			0.892
Yes	48 (43.6)	47 (42.7)	
No	62 (56.4)	63 (57.3)	
Parents' exposure to lead due to work/hobbies†			0.686
Yes	54 (49.1)	57 (51.8)	
No	56 (50.9)	53 (48.2)	
Immigrant/refugee status†			
Yes	13 (11.8)	10 (9.1)	0.509
No	97 (88.2)	100 (90.9)	

**: median (IQR) (Mann-Whitney U test), †: n(%) (Chi-square analysis)*

A total of 112 participants (50.9%) were female. Among all participants, 95 (43.2%) lived in a house located on the roadside, and 111 (50.5%) had parents with occupational or hobby-related lead exposure. Twenty-three participants (10.5%) were immigrants or refugees (Table I).

All participants had plastic toy exposure, and none of the children lived in or regularly visited a house built before 1950.

The median age of the anemia group was significantly lower than that of the control group (p=0.002). The proportion of children older than 5 years was significantly higher in the control group than in the anemia group (p=0.008). There were no significant differences between the anemia and control groups in terms of sex, residence on the roadside, parental occupational or hobby-related lead exposure, or immigrant/refugee status (p=0.106, p=0.892, p=0.686, and p=0.509, respectively). The comparison of demographic and exposure-related characteristics between the anemia and control groups is shown in Table II.

When laboratory findings were compared between the anemia and control groups, hemoglobin (11.0 [9.6–11.7] vs. 13.2 [12.4–14.0] g/dL), hematocrit (34.1 [30.1–36.1] vs. 39.8 [37.3–41.8]%), and mean corpuscular volume (77.2 [72.3–80.3] vs. 81.8 [78.0–84.5] fL) values were significantly lower in the anemia group than in the control group (p<0.001 for all). In contrast, red cell distribution width was significantly higher in the anemia group than in the control group (15.0 [13.5–18.5]% vs. 13.2 [12.7–13.8]%; p<0.001).

The mean BLL was 7.57±0.34 µg/dL in the anemia group and 7.61±0.34 µg/dL in the control group. The lowest BLL was 6.8 µg/dL, and the highest BLL was 8.6 µg/dL. There was no significant difference in BLLs between the anemia and control groups (p=0.410).

Participants whose parents had occupational or hobby-related lead exposure, including battery production, lead paint removal, mining, scrap recycling, ceramic glazing, or lead soldering, had significantly higher BLLs than those without such exposure (p<0.001). Immigrant or refugee children also had significantly higher BLLs than non-immigrant and non-refugee children (p<0.001). There were no significant differences in BLLs according to age category, sex, or residence on the roadside (p=0.136, p=0.724, and p=0.235, respectively). The comparison of BLLs according to various parameters is summarized in Table III.

Table III: Comparison of BLLs according to various parameters among all participants

Variable	BLL (µg/dL)	p
Age category*		
≤ 5 years old	7.55±0.32	0.136
> 5 years old	7.61±0.29	
Sex*		
Female	7.58±0.31	0.724
Male	7.59±0.30	
Living in a house on the roadside*		
Yes	7.56±0.32	0.235
No	7.54±0.34	
Parents' exposure to lead due to work/hobbies*		<0.001
Yes	7.69±0.34	
No	7.43±0.28	
Immigrant/refugee status*		
Yes	7.85±0.38	<0.001
No	7.54±0.33	

**: mean±SD (Student's t test)*

Discussion

In this study, the mean BLL of children living in Malatya and its surrounding areas was 7.6±0.3 µg/dL, and none of the participants had a BLL below 5 µg/dL. This finding indicates that BLLs in our study population were above both the current CDC blood lead reference value of 3.5 µg/dL and the previous reference value of 5 µg/dL (1,2). Although BLLs in our cohort did not reach levels traditionally associated with overt lead poisoning, current evidence emphasizes that there is no safe BLL in children and that even low-level exposure may have adverse neurodevelopmental consequences (2,3). Therefore, the BLLs detected in our region should be considered important from a public health perspective.

A previous study conducted in Malatya in 1998 reported a mean BLL of 21.8 µg/dL in children living in the city center and surrounding villages (12). Compared with that study, the mean BLL in our cohort was substantially lower. This decrease may reflect the effect of environmental regulations, the global phase-out of leaded petrol, and increased awareness of lead exposure over time (14). Nevertheless, the persistence of BLLs above current reference values suggests that lead exposure has not been eliminated. In the post-leaded petrol era, children may continue to be exposed to lead through contaminated soil and dust, industrial emissions, battery production and recycling, old paints, water systems, toys, jewelry, cookware, spices, cosmetics, and traditional products (3,4,15,16).

The absence of a significant difference in BLLs between children with microcytic anemia and healthy controls was one of the main findings of this study. Lead toxicity is

included in the differential diagnosis of microcytic anemia because lead interferes with heme synthesis and erythrocyte survival (7,8). In addition, iron deficiency may increase lead absorption through shared gastrointestinal transport pathways (8,9). However, the relationship between BLL and anemia is complex and may be influenced by the degree and duration of exposure, nutritional status, socioeconomic conditions, inflammation, parasitic infections, and other causes of microcytosis. Clinically apparent anemia is more likely to occur at higher or prolonged BLLs, whereas low-level exposure may primarily affect neurodevelopment before hematologic abnormalities become evident (3,8). Therefore, the lack of association between BLL and hemoglobin level in our study does not exclude the clinical relevance of lead exposure.

Our findings suggest that lead exposure in this region is not limited to children with microcytic anemia. The similar BLLs observed in healthy controls and anemic children may indicate a broader environmental exposure affecting the general pediatric population. For this reason, lead exposure should not be considered only in children with anemia. However, BLL measurement remains important in children with unexplained microcytic anemia, treatment-resistant iron deficiency anemia, pica, developmental delay, abdominal symptoms, or a history of environmental risk factors.

In our study, refugee and immigrant children had statistically significantly higher BLLs than non-refugee and non-immigrant children. However, the absolute difference between the groups was only 0.2 µg/dL. Although previous studies have reported increased lead exposure among migrant and refugee children, the small absolute difference observed in our study should be interpreted with caution, considering its limited clinical significance and the potential analytical variability of blood lead measurements. In a large study of resettled refugee children in the United States, Pezzi et al. (17) reported elevated BLLs in a considerable proportion of children screened after arrival. Similarly, Geltman et al. (18) reported that 41.9% of refugee children resettled in Massachusetts had BLLs ≥5 µg/dL, and that anemia and region of origin were associated with elevated BLLs. In Greece, Tanaka et al. (19) found that newly arrived migrant children had significantly higher BLLs than native children, with BLLs ≥5 µg/dL detected in 27.7% of migrant children compared with 1.2% of native children. More recently, Hunnewell et al. (20) evaluated immigrant children seeking humanitarian protection and emphasized the need for lead screening and anemia assessment in newcomer populations .

Several mechanisms may explain the higher BLLs observed among refugee and immigrant children. These children may have been exposed to lead before migration through industrial pollution, informal recycling, leaded petrol residues, contaminated soil, traditional products, or unsafe cookware. After migration, crowded housing, poor nutrition, old buildings, imported foods or spices, traditional cosmetics, and limited access to preventive health services may contribute to ongoing exposure (10,11,21). Fellows et al. (21) demonstrated that aluminum cookpots used by Afghan refugee families could contain and leach high levels of lead, highlighting the importance of culturally specific exposure sources. These findings support the need for detailed environmental exposure history and targeted screening in refugee and immigrant children.

Children under five years of age are generally considered at higher risk for lead exposure because of frequent hand-to-mouth behavior, increased gastrointestinal absorption, and greater vulnerability of the developing nervous system (3,5). However, we did not find a significant difference in BLLs between children younger than five years and older children. This may be related to the widespread nature of environmental exposure in the region, the sample size, or the distribution of exposure sources across age groups. Similar findings have been reported in some studies in which risk was more closely related to environmental and behavioral factors than to age alone (15,16). Therefore, although younger children should remain a priority group for prevention, school-aged children should not be overlooked in regions with ongoing environmental exposure.

Limitations

This study has several limitations. First, it was cross-sectional and BLL was measured at a single time point; therefore, the duration and timing of exposure could not be determined. Second, environmental lead measurements were not performed in soil, dust, drinking water, paint, toys, cookware, spices, or cosmetics. Thus, the exact sources of exposure could not be identified. Third, detailed data on nutrition, iron status, socioeconomic conditions, parental occupation, housing characteristics, and traditional product use were limited. Finally, the number of refugee and immigrant children may not have been sufficient to identify all subgroup-specific risk factors. Despite these limitations, our study is valuable because it compares BLLs between children with microcytic anemia and healthy controls and draws attention to elevated BLLs among refugee and immigrant children in our region.

Conclusion

In conclusion, although the mean BLL in children living in Malatya and its surrounding areas has decreased compared with previous regional data, it remains above current reference values. The absence of a significant difference between children with microcytic anemia and healthy controls suggests that lead exposure may affect the wider pediatric population rather than only children with anemia. Higher BLLs among refugee and immigrant children indicate that this group requires special attention. Regional screening strategies, environmental source control, nutritional support, family education, and cooperation between health authorities and local governments are needed to reduce preventable lead exposure and protect child development.

Ethics committee approval

This study was conducted in accordance with the Helsinki Declaration Principles. The study was approved by İnönü University (16.05.2018, reference number: 2018/65).

Contribution of the authors

Study conception and design: AKA, AA; data collection: SA, AKA; analysis and interpretation of results: AKA, YT, AA, YÖ; draft manuscript preparation: AKA, AA, YÖ, SA. All authors reviewed the results and approved the final version of the article.

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Conflict of interest

The authors declare that there is no conflict of interest.

References

1. Ruckart PZ, Jones RL, Courtney JG, et al. Update of the blood lead reference value — United States, 2021. MMWR Morb Mortal Wkly Rep 2021; 70(43):1509-12. https://doi.org/10.15585/mmwr.mm7043a4
2. Centers for Disease Control and Prevention. CDC updates blood lead reference value [Internet]. 2024. Available at: https://www.cdc.gov/lead-prevention/php/news-features/updates-blood-lead-reference-value.html (Accessed on 2026 Jul 6).
3. World Health Organization. Lead poisoning [Internet]. 2024. Available at: https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health (Accessed on 2026 Jul 6).
4. Council on Environmental Health. Prevention of childhood lead toxicity. Pediatrics 2016; 138(1): e20161493. https://doi.org/10.1542/peds.2016-1493
5. Centers for Disease Control and Prevention. About childhood lead poisoning prevention [Internet]. 2025. Available at: https://www.cdc.gov/lead-prevention/about/index.html (Accessed on 2026 Jul 6).
6. Ettinger AS, Wengrovitz AG. Guidelines for the identification and management of lead exposure in pregnant and lactating women [Internet]. Atlanta: Centers for Disease Control and Prevention; 2010. Available at: https://www.cdc.gov/lead-prevention/media/pdfs/2025/03/cdc_147837_DS1.pdf (Accessed on 2026 Jul 6).
7. Halmo L, Nappe TM. Lead toxicity. In: StatPearls [Internet]. Treasure Island: StatPearls Publishing; 2025. Available at: https://www.ncbi.nlm.nih.gov/books/NBK541097/ (Accessed on 2026 Jul 6).
8. Mayans L. Lead poisoning in children. Am Fam Physician 2019; 100(1): 24-30.
9. Farkhondeh T, Mansouri B, Binkowski LJ, et al. Blood lead concentrations in children with iron deficiency anemia: A systematic review and meta-analysis. Environ Sci Pollut Res Int 2022; 29(3): 3199-212. https://doi.org/10.1007/s11356-021-17301-z
10. Centers for Disease Control and Prevention. Lead: Immigrant and refugee health domestic guidance [Internet]. 2026. Available at: https://www.cdc.gov/immigrant-refugee-health/hcp/domestic-guidance/lead.html (Accessed on 2026 Jul 6).
11. Balza JS, Awoyinka I, Kaeppler C, Cusatis R, Flynn KE. Lead poisoning in refugee children living in the United States: A systematic review of case studies. Hyg Environ Health Adv 2023; 6: 100057. https://doi.org/10.1016/j.heha.2023.100057
12. Balat A, Gül A, Özgen Ü, et al. Malatya ili şehir merkezi ve köylerinde yaşayan çocuklar ile çıraklarda kan kurşun düzeylerinin karşılaştırılması. Yeni Tıp Dergisi 1998; 15(4): 203-205.
13. Lanzkowsky P, editor. Manual of Pediatric Hematology and Oncology. 4th ed. Burlington, MA: Academic Press; 2005.
14. United Nations Environment Programme. Era of leaded petrol over, eliminating a major threat to human and planetary health [Internet]. 2021. Available at: https://www.unep.org/news-and-stories/press-release/era-leaded-petrol-over-eliminating-major-threat-human-and-planetary (Accessed on 2026 Jul 6).
15. Cheng XJ, Li GB, Zhang SS, et al. Factors associated with blood lead levels in children in Shenyang, China: A cross-sectional study. BMC Pediatr 2022; 22(1): 122. https://doi.org/10.1186/s12887-022-03182-9
16. Li MM, Jiao XT, Zhang J, et al. Prevalence and risk factors of elevated blood lead levels in 0–6-year-old children: A national cross-sectional study in China. Front Public Health 2025; 13: 1546842. https://doi.org/10.3389/fpubh.2025.1546842
17. Pezzi C, Lee D, Kennedy L, et al. Blood lead levels among resettled refugee children in select US states, 2010–2014. Pediatrics 2019; 143(5): e20182591. https://doi.org/10.1542/peds.2018-2591
18. Geltman PL, Smock L, Cochran J. Trends in elevated blood lead levels using 5 and 10 µg/dL levels of concern among refugee children resettled in Massachusetts, 1998–2015. Public Health Rep 2019; 134 (6): 608-16. https://doi.org/10.1177/0033354919874078
19. Tanaka M, Petsios K, Dikalioti SK, et al. Lead exposure and associated risk factors among new migrant children arriving in Greece. Int J Environ Res Public Health 2018; 15(6): 1057. https://doi.org/10.3390/ijerph15061057
20. Hunnewell J, Olivo-Freites C, Danaher F, et al. Lead screening among immigrant children seeking humanitarian protection in New York and Massachusetts, 2022–2024. Public Health Rep 2026. https://doi.org/10.1177/00333549261421896
21. Fellows KM, Samy S, Rodriguez Y, et al. Investigating aluminum cookpots as a source of lead exposure in Afghan refugee children resettled in the United States. J Expo Sci Environ Epidemiol 2022; 32(3): 451-60. https://doi.org/10.1038/s41370-022-00431-y