SQUMJ
Sultan Qaboos University Medical Journal

Manuscript 2840

Lead and Iron Levels in Maternal and Umbilical Cord Blood in Basrah, Iraq

Balqees Kadhim Hasan

Jafar Sadek Abdulazeez

Meaad Kadhum Hassan

Hamid Jaddoah Abbas

Lamia Mustafa Al-Naama

SULTAN QABOOS UNIVERSITY MEDICAL JOURNAL 2025;25:319–327

Scan the QR to view the full-text article on the journal website

ORIGINAL STUDY

Lead and Iron Levels in Maternal and Umbilical Cord Blood in Basrah, Iraq

Balqees Kadhim Hasan [a], Jafar Sadek Abdulazeez [b], Meaad Kadhum Hassan [c,*], Hamid Jaddoah Abbas [d], Lamia Mustafa Al-Naama [e]

[a] Department of Human Anatomy, College of Medicine, University of Basrah, Basrah, Iraq
[b] Department of Pediatrics, Basrah Maternity and Children Hospital, Basrah Health Directorate, Basrah, Iraq
[c] Department of Pediatrics, College of Medicine, University of Basrah, Basrah, Iraq
[d] Department of Biochemistry, Al-Zahraa Medical College, University of Basrah, Basrah, Iraq
[e] Department of Biochemistry, College of Medicine, University of Basrah, Basrah, Iraq

Advances in Knowledge

- The effects of blood lead levels (BLL) in pregnant women on their newborns are controversial and differ from country to country and even in different districts within the same country.
- The study examines the impact of maternal BLLs on their babies in Basrah, Iraq where previous studies revealed high BLL among the population.

Application to Patient Care

- The results of this study can help establish preventive measures to reduce human lead exposure and monitor lead levels in pregnant women.

ABSTRACT

Objectives: Lead can pass from a mother to her developing foetus and is associated with well-established risks for the foetus. This study aimed to evaluate maternal and cord iron and lead levels and study the association of maternal and cord blood lead levels (BLLs) with newborn anthropometric measurements. ***Methods:*** This cross-sectional study was conducted at Basra Maternity and Children Hospital, Basrah, Iraq, and included women and their newborns over the period from January through June 2023. Blood samples from mothers and umbilical cords were collected and sent to determine the complete blood count and lead and iron levels. Linear regression and Pearson correlation were used to assess the association of maternal and cord BLLs with different maternal and neonatal variables. ***Results:*** A total of 140 women and their newborns were included in this study. There was a significantly lower maternal haemoglobin (10.6 ± 1.4 g/dL) and serum iron (93.5 ± 44.8 μg/dL) levels compared to newborn levels (13.3 ± 1.8 g/dL and 135.0 ± 76.5 μg/dL, respectively; $P < 0.001$). A significant negative correlation between maternal haemoglobin and cord BLLs ($R2 = 0.12$; $P < 0.001$) and a significant positive correlation between maternal and cord iron ($B = 0.41$; $P < 0.05$) levels and maternal BLLs with both cord iron ($B = 4.78$; $P < 0.05$) and cord BLLs ($R2 = 0.29$; $P < 0.001$) were reported. Furthermore, the Pearson correlation revealed a significant negative correlation between cord BLLs and infant birth weight ($R2 = 0.06$; $P = 0.01$). ***Conclusions:*** This study found that maternal BLLs were positively associated with both cord iron and cord BLLs. The cord BLL was negatively associated with maternal haemoglobin levels and infant birth weight. Preventive measures to reduce human lead exposure and monitor lead levels in pregnant women are important.

Keywords: Lead; Iron; Cord Blood; Basrah; Iraq

Received 21 May 2024; revised 22 October 2024; accepted 12 November 2024.
Available online 16 May 2025

* Corresponding author.
E-mail address: alasfoor_mk@yahoo.com (M. K. Hassan).

https://doi.org/10.18295/2075-0528.2840

1. Introduction

Environmental contamination with hazardous heavy metals is considered an important health issue for individuals of all age groups worldwide. These metals can accumulate in different organs of the human body causing significant health problems.[1]

Exposure to lead continues to affect at-risk age groups globally, including women of childbearing age and children, especially in developing countries.[2]

Exposure to lead can affect the central nervous system (CNS), gastrointestinal tract, cardiovascular and renal systems. It also has immunological and haematological adverse effects. Children are especially susceptible to the toxic effects of lead on the CNS, and even exposure to relatively low levels may result in severe and, in some children, irreversible neurological damage.[3] Even children with mild elevation in blood lead levels (BLLs) have a greater risk of developing various neurological and behavioural problems that can continue into adolescence.[4] Although blood lead concentrations have reduced worldwide following a decline in the use of lead in gasoline, paint, plumbing and soldering, significant sources of exposure to lead are still present in many countries, especially developing countries and countries with transitional economies.[3]

Iron deficiency is reported to be associated with increased BLLs, as lead is a seriously detrimental element to iron metabolism.[5]

Lead can also pass from a mother to her developing foetus through the placenta as early as 12 weeks gestation until birth, and there is a strong correlation between maternal and umbilical cord BLLs.[4,6] Lead is destructive to the developing central nervous system because of the incomplete blood-brain barrier. Elevated BLLs in pregnant women, even levels $<10\ \mu$/dL, can cause abortion, preterm birth, low birth weight and delayed development in children.[4] The Centres for Disease Control and Prevention recommended a reference BLL of 3.5 mg/dL to prevent the deleterious effects on children. However, no level of lead is safe.[7]

The effect of lead on body weight at birth represents a critical medical issue, as low birth weight is an important predictor of neonatal mortality and morbidity.[8] However, previous studies concerning the relation between maternal BLLs and infant birth weight have shown conflicting results. Some researchers reported a significant negative association between maternal BLLs and infant birth weight, while others did not report such an association.[9–11]

Despite the well-established risks associated with lead exposure, routine prenatal lead screening, BLL screening in children and lead educational interventions are not a standard of care.[4]

Several studies about BLLs among Iraqi populations have revealed high BLLs. However, these studies were carried out on selected at-risk groups like those working in the petroleum industry, fuel stations, and other at-risk workers.[12–14]

In Basrah, previous studies also reported a high mean BLLs in children and adults.[15,16] However, knowledge about maternal iron and BLLs and their impact on their baby is lacking. Assessing iron and BLLs in pregnant women and their babies is important for the development and implementation of effective regulatory steps that will reduce lead exposure in this risky population. Therefore, the current study aimed to determine the maternal and cord iron and lead levels and study the association between maternal and cord BLLs and neonatal anthropometric measurements.

2. Methods

This analytical cross-sectional study was conducted at Basra Maternity and Children Hospital, Basrah, Iraq, from January to June 2023 and included women and their newborns. Mothers were interviewed using a questionnaire developed for this study. Data obtained included maternal age, residence, educational level, milk consumption, smoking, Kohl use (a traditional powder-like eyeliner), dairy products ingestion, tea consumption, coffee intake and iron supplement during pregnancy.

Only mothers with full-term, singleton pregnancies who attended Basra Maternity and Children Hospital during the study period were recruited. Maternal weight and height were measured, and body mass index was calculated. Women with chronic medical conditions or infectious diseases were excluded. All neonates were examined, and gestational age (GA), weight, length and occipitofrontal circumference (OFC) were assessed.

Maternal blood samples were collected from peripheral veins by using a sterile technique at the time of delivery, and cord blood samples were taken from their newborns' umbilical veins immediately following delivery, after cleaning and stabilising the newborns.

Each sample of blood (approximately 5 mL) was divided into 2 parts. The first part included 3 mL that were added to an ethylenediaminetetraacetic acid tube; 2 mL were used for the measurements of complete blood count variables while 1 mL was subjected to immediate acid digestion was used for lead estimation.

The other part included 2 mL which were transferred to a gel tube (without anticoagulant) and were allowed to clot. The serum was separated and stored at - 20 °C until the iron level was measured.

Table 1. Selected clinical characteristics of newborns and their mothers (N = 140).

Characteristic	n (%)
Maternal age in years	
≤20	21 (15.0)
21–30	84 (60.0)
31–40	32 (22.9)
>40	3 (2.1)
Mean ± SD	27.2 ± 6.0
Median	27.0
IQR	8
Residence	
Centre	88 (62.9)
Periphery	52 (37.1)
Educational level	
Illiterate	15 (10.7)
Primary	69 (49.3)
Secondary	34 (24.3)
Higher	22 (15.7)
Milk consumption	83 (59.3)
Kohl use	46 (32.9)
Mean BMI ± SD (range)	27.6 ± 3.5 (18.1–37.8)
Newborn-related factors	
Mean birth weight ± SD (range)	3.2 ± 0.4 (1.8–4.6)
Sex	
Male	78 (55.7)
Female	62 (44.3)
Mean gestational age in weeks ± SD (range)	38.3 ± 3.1 (36–41)

SD = standard deviation; BMI = body mass index.

The haemoglobin level was measured by a Sysmex XN 350 analyser (Sysmex Corporation, Kobe, Japan) within 30 minutes of sample collection.

Lead levels in digested blood samples were measured by an AA - 7000 atomic absorption spectrometer analyser (Shimadzu Corporation, Kyoto, Japan). Atomic absorption spectroscopy analyses and measures the concentration of metal atoms/ions in a sample based on the principle that atoms/ions can absorb light at specific unique wavelengths. When a sample containing a particular metal, is exposed to light at the specific wavelength of the metal, only that metal atom will absorb this light. The amount of light absorbed at this defined wavelength is directly proportional to the concentration of the absorbing metal. Lead is a toxic metal, and there is no safe level of exposure. However, a blood lead level should be ≤3.5 μg/dL for children and <5 μg/dL for adults.[17,18]

The serum iron level was measured by spectrophotometer (Architect Abbott c4000 analyzer, Abbott Laboratory Inc., Abbott Park, Illinois, USA). The normal values of serum iron are 60–160 μ/dL for adult females and 100–250 μ/dL for neonates.[19]

Data were analysed using the Statistical Packages for Social Sciences (SPSS), Version 23.0 (IBM Corp., Armonk, New York, USA). Data are expressed as the mean ± standard deviation or number and percentage where appropriate. Comparisons of proportions were performed by cross tab using an independent t-test when each cell had a mean ± standard deviation in 1 × 2 tables. Multiple groups were also analysed using a linear regression unstandardised coefficient (B). Pearson correlation was used to assess the association between maternal and cord BLLs with neonatal anthropometric measurements. Multivariate analysis was utilised to examine the independent effects of certain variables on neonatal anthropometric indices. These variables were maternal age, residence, GA, milk consumption, dairy products ingestion, tea and coffee consumption during pregnancy, maternal haemoglobin, iron level and BLL, cord haemoglobin and cord BLL. For all tests, a P value of <0.05 was considered statistically significant.

3. Results

A total of 140 mothers and their newborns were recruited for this study. The maternal age ranged from 15 to 42 years (interquartile range = 8), with a mean of 27.2 ± 6.0 years. Most mothers (62.9%) were from the centre of Basrah, and only 15.7% had higher education. Kohl was used by 32.9% of the mothers and 59.3% were consuming milk. None of the mothers were smokers. Concerning newborns, the mean GA was 38.3 ± 3.1 weeks, while the mean birth weight was 3.2 ± 0.4 kg [Table 1].

Table 2. Maternal and cord haemoglobin, iron and lead levels (N = 140).

Parameter	Maternal			Cord			*P* value*
	Mean ± SD	Median	Range	Mean ± SD	Median	Range	
Haemoglobin in g/dL	10.6 ± 1.4	10.7	5.8–13.8	13.3 ± 1.8	13.3	8.2–19.8	< 0.001
Iron in μg/dL	93.5 ± 44.8	80	24–303	135.0 ± 76.5	98.75	35–390	< 0.001
Lead in μg/dL	7.6 ± 4.1	7	1–26	6.8 ± 3.9	6	1–22	0.102

SD = standard deviation.

**Using an Independent t-test was used.*

Table 3. Correlation between maternal and cord haemoglobin, iron and lead levels.

Parameter	Cord					
	Haemoglobin		Serum iron		Blood Lead	
	B	*P* value	B	*P* value	B	*P* value
Mother						
Haemoglobin	0.12	0.326	0.97	0.845	−0.58	0.011
Serum iron	0.002	0.582	0.41	0.007	−0.001	0.860
Blood Lead	0.02	0.584	4.78	0.003	0.45	< 0.001

B = linear regression unstandardised coefficient.

The study revealed significantly lower maternal haemoglobin (10.6 ± 1.4 g/dL) and serum iron (93.5 ± 44.8 μg/dL) levels compared to newborn levels (13.3 ± 1.8 g/dL and 135.0 ± 76.5 μg/dL, respectively; $P < 0.001$). However, there was no significant difference in the mean BLL between mothers and their newborns (7.5 ± 4.1 versus 6.8 ± 3.9 μg/dL; $P = 0.102$) [Table 2]. High BLLs were reported in 110 (78.6%) mothers and 123 (87.9%) neonates.

Linear regression analysis did not show any significant correlation between maternal BLLs and selected maternal variables such as age (B = 0.008; $P = 0.948$), kohl use (B = −1.070; $P = 0.542$), milk consumption (B = −1.704; $P = 0.384$), dairy products consumption (B = −1.503; $P = 0.417$), tea consumption (B = −0.754; $P = 0.725$), coffee intake (B = −1.862; $P = 0.293$) and iron supplement (B = −1.495; $P = 0.411$).

A significant negative correlation between maternal haemoglobin and cord BLLs (R2 = 0.12; $P = 0.011$) and a significant positive correlation between maternal and cord iron levels (B = 0.41; $P = 0.007$) and maternal BLLs with both cord iron (B = 4.78; $P = 0.003$) and cord BLLs (R2 = 0.29; $P < 0.001$) were observed, while no association was seen between maternal serum iron and cord BLLs (R2 = 2.70, $P = 0.951$) [Table 3 and Fig. 1].

The study did not reveal any significant association between maternal BLLs and neonatal anthropometric measurements ($P > 0.05$) [Fig. 2]. However, the Pearson correlation revealed a significant negative correlation between cord BLLs and infant birth weight (R2 = 0.06; $P = 0.01$) [Fig. 3].

On submitting all variables that could potentially affect neonatal anthropometric indices to multivariate regression analysis, the only significant predictor of birth weight was GA (B = 0.282; $P < 0.001$), while for the OFC, significant predictors were maternal age (B = 0.083; $P < 0.001$) and cord BLL (B = −0.056; $P = 0.045$).

4. Discussion

Lead is one of the most widespread harmful heavy metals and hazardous pollutants associated with adverse effects on the health of humans.[20]

The current study investigated the levels of lead and iron in maternal and umbilical cord blood and the association of both maternal and cord BLLs with neonatal anthropometric measurements at birth. This study revealed a significant negative correlation between maternal haemoglobin and cord BLL and a significant positive correlation between maternal and cord iron levels and maternal BLL with both cord iron and cord BLLs.

Although the mean maternal BLLs were higher (7.6 μg/dL) than cord BLLs (6.8 μg/dL), the difference was not statistically significant. The mean maternal BLL was lower than that reported previously in Basrah by Al Naama *et al.* in adult females (10.12 ± 2.98 μg/dL).[16] However, the current study results were higher than those of Al-Jawadi *et al.*, who reported a mean maternal BLL of 3.26 ± 1.91 μg/dL (range: 0.50–22.39 μg/dL) and a mean cord BLL of 2.29 ± 2.11 μg/dL (range: 0.30–22.91 μg/dL) in Mousl Province in northern Iraq but lower than those of Sahb *et al.* who reported a mean maternal BLL of 10.31 ± 3.41 μg/dL in Babylon Province in the centre of Iraq.[21,22] The relatively high levels of lead

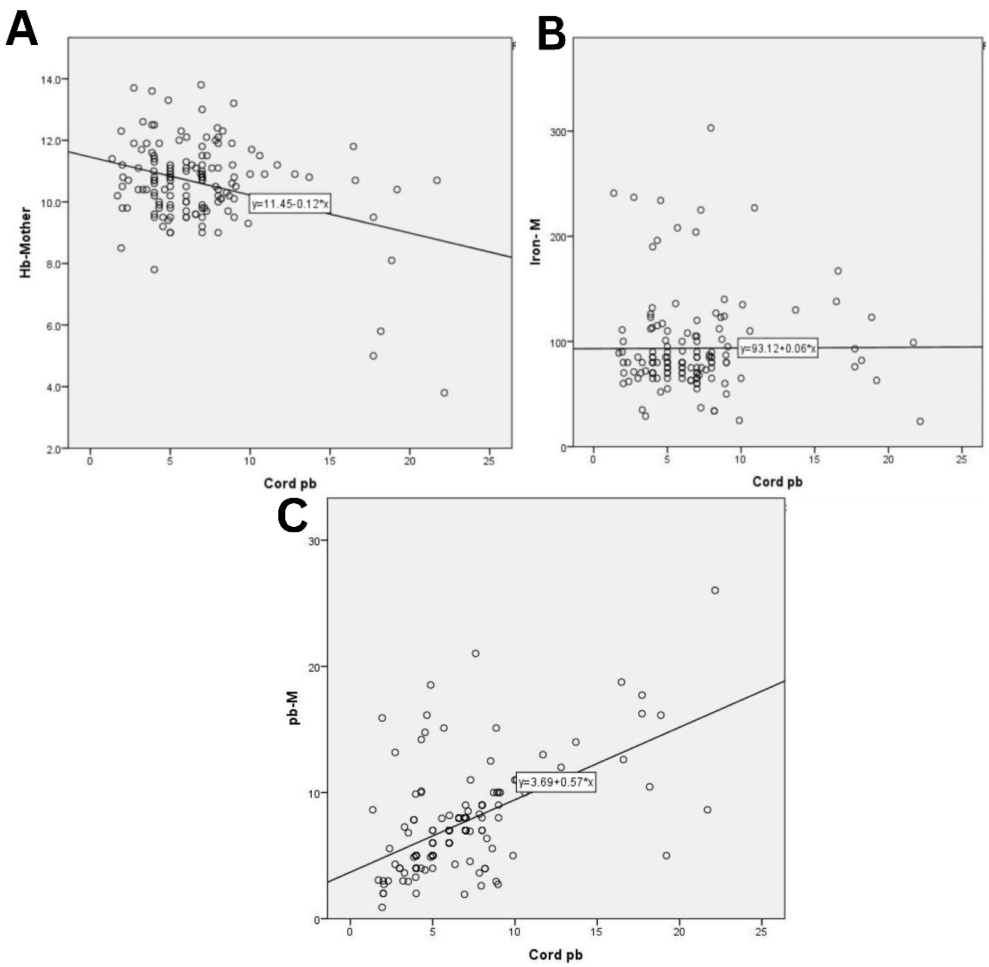

Fig. 1. Pearson correlation was used to show the correlation between cord lead levels and (**A**) maternal haemoglobin ($R2 = 0.12$; $P < 0.001$), (**B**) maternal iron ($R2 = 2.70$; $P = 0.951$) and (**C**) maternal lead levels ($R2 = 0.29$; $P < 0.001$).

in Iraqi society can be attributed to higher exposure to lead through exposure to gasoline automobiles, paper products, discarded rubber, battery casings and Kohl use in women.[16]

The significant positive association between maternal and cord lead levels is consistent with the findings of other studies in different countries.[23–25] However, Reddy *et al.* did not report such an association in India.[26] The lead in maternal blood passes to her foetus through the placenta and high levels can have long-term adverse effects on offspring development.[25] However, the differences between different studies can be explained by the fact that the transfer of maternal lead to the foetus can be affected by many factors, including maternal blood pressure, haemoglobin, seasonal variation (delivery in winter) and stressful conditions.[27]

The mean maternal haemoglobin level was 10.6 ± 1.4 g/dL, with a significant negative correlation between maternal haemoglobin and cord BLLs. These findings are in agreement with the levels reported by El Khaleegy *et al.* in Egypt, who reported a comparable mean maternal haemoglobin level (10.5 g/dL) and a significant negative association between maternal haemoglobin and cord BLLs;[28] Al-Jawadi *et al.*, reported that haemoglobin level <11 g/dL was a significant predictor of umbilical blood lead level ≥ 5 μg/dL in Iraq and that iron supplements during pregnancy had a significant protective effect against the development of high cord BLLs.[21]

The mean serum iron level in cord blood was significantly higher than in maternal blood, with a significant positive correlation between maternal and cord iron levels. This result is consistent with Shih-Hui *et al.*'s study, who found a positive correlation of iron ($r = 0.17$; $P = 0.038$) in paired maternal/foetal samples with a higher median iron level in cord blood compared to maternal blood in Taiwan.[29] Iron supply to the foetus, through the placenta, is an active process that does not depend on the maternal iron

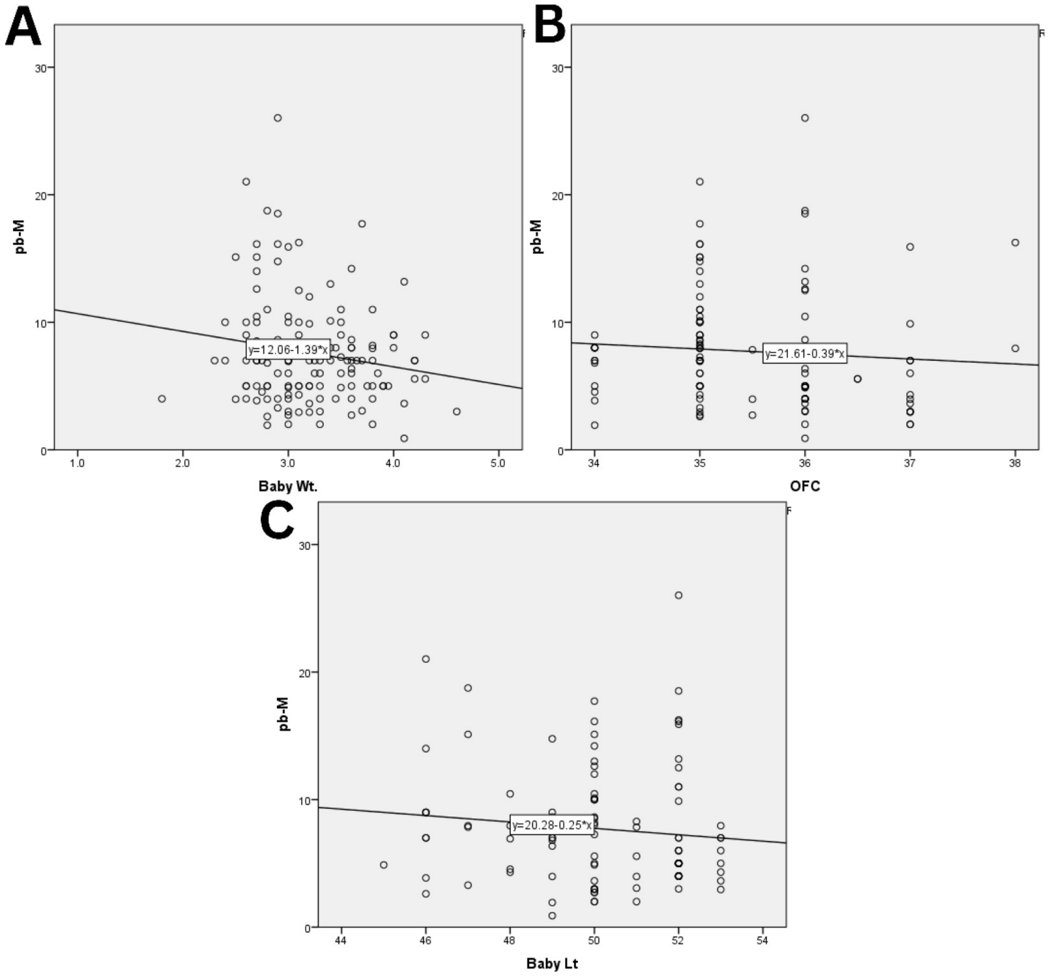

Fig. 2. Pearson correlation was used to show the correlation between maternal blood lead level and (**A**) baby weight (R2 = 0.02; *P* = 0.051), (**B**) neonates occipito-frontal circumference (OFC; R2 = 0.006; *P* = 0.417) and (**C**) baby length (R2 = 0.012; *P* = 0.247).

status. However, it was found that iron transfer is reduced when the mother becomes anaemic, and this can predispose her foetus to iron deficiency.[30]

The current study found a significant positive correlation between maternal BLLs and cord iron levels. This can be attributed to the fact that iron deficiency in pregnant women can lead to an increase in lead accumulation in these women during pregnancy, and both iron and lead can affect the pathways involved in the synthesis of haemoglobin.[31]

Another finding is the significant negative correlation between cord BLLs and infant weight at birth. The results of the various studies concerning the association between cord BLLs and infant anthropometric indices at birth are controversial. The current study results agree with those of Torabi *et al.*, who reported a significant inverse relation between umbilical cord BLLs and birth weight in Iran ($P = 0.008$). However, there was no significant association between cord BLLs and head circumference and infant height at birth.[32] Another study in Iran by Neda *et al.* reported that excess lead in the blood caused a decrease in birth weight, length and occipitofrontal circumference of the newborns, although the decrease in birth weight was not significant ($r = -0.141$; $P = 0.092$).[33] El Khaleegy *et al.* reported that umbilical BLLs correlated negatively with neonatal birth weight, head circumference and length in Egypt.[28] Other studies by Ladele *et al.* in Nigeria and Dalili *et al.* in Iran did not report any significant relation between cord BLLs and the growth parameters of the newborn.[23,24]

The BLL in a neonate is dependent on many factors including maternal environmental exposure to lead, its storage in the body and release in blood during pregnancy and the maternal diet and nutritional status during pregnancy.[33]

The current study has many limitations. For example, maternal diet and iron and vitamin supplements were not studied thoroughly. Other limitations were the relatively small sample size and that BLLs were

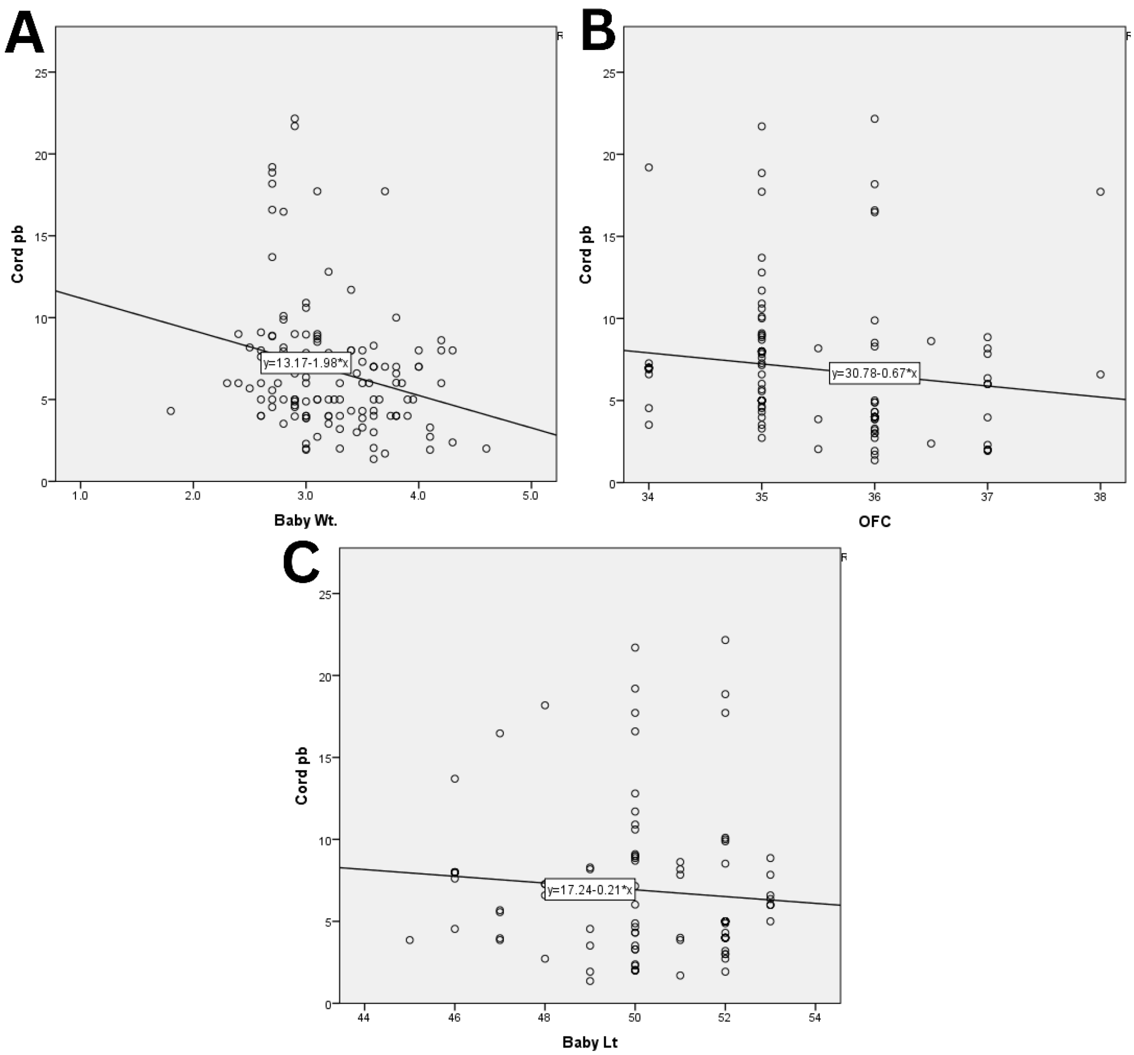

Fig. 3. Pearson correlation was used to show the correlation between cord blood lead level and (**A**) baby weight (R2 = 0.06; *P* = 0.01), (**B**) baby occipitofrontal circumference (OFC; R2 = 0.02; *P* = 0.140) and (**C**) baby length (R2 = 0.009; *P* = 0.316).

assessed at delivery only, as it is well known that prolonged exposure to lead may result in more harmful effects on foetuses.

5. Conclusion

The current study revealed that a high maternal BLL was associated with both cord iron and cord BLLs and adds to the limited existing evidence of high BLLs in the Iraqi population. The study also highlighted that the presence of a high mean cord BLL was negatively associated with low maternal haemoglobin levels and infant birth weight. The study findings have provided baseline data that can be transferred to local and national decision-makers to implement regulatory measures to reduce lead exposure and prevent its harmful effects. Although routine testing of pregnant women for BLLs is not done, a multifarious approach appropriate for the local situation in Basrah is needed, which should include implementing a risk assessment screening tool for lead exposure, educational programmes about the risk of elevated BLLs on the health of pregnant women and their babies, combined with adequate dietary intake of calcium, iron, zinc, vitamins C, D and E, which are known to lower lead absorption.

Authors' Contribution

Balqees Kadhim Hasan: Conceptualization, Investigation, Formal analysis, Writing - Original Draft, Writing - Review & Editing. **Jafar Sadek Abdulazeez**: Investigation, Formal analysis, Writing - Original Draft, Writing - Review & Editing. **Meaad**

Kadhum Hassan: Conceptualization, Investigation, Formal analysis, Writing - Original Draft, Writing - Review & Editing. **Hamid Jaddoah Abbas**: Investigation, Formal analysis, Writing - Original Draft, Writing - Review & Editing. **Lamia Mustafa Al-Naama**: Conceptualization, Investigation, Formal analysis, Writing - Original Draft, Writing - Review & Editing.

Ethics Statement

The Ethical and Scientific Committee of the College of Medicine, University of Basrah, authorised this study on June 2022 (Project ID: 030401-114-2022). Informed consent was obtained from the mothers before enrolment in the study.

Conflict of Interest

The authors declare no conflicts of interest.

Funding

No funding was received for this study.

Data Availability

Data are available from the corresponding author upon reasonable request.

References

1. Wu X, Cobbina SJ, Mao G, Xu H, Zhang Z, Yang L. A review of toxicity and mechanisms of individual and mixtures of heavy metals in the environment. Environ Sci Pollut Res Int 2016; 23:8244–59. https://doi.org/10.1007/s11356-016-6333-x.
2. Kordas K, Ravenscroft J, Cao Y, McLean EV. Lead exposure in low and middle-income countries: perspectives and lessons on patterns, injustices, economics, and politics. Int J Environ Res Public Health 2018; 15:2351. https://doi.org/10.3390/ijerph15112351.
3. World Health Organization. Childhood lead poisoning. Exposure to lead: A major public health concern, 2nd edition. World Health Organization 2021. From: https://www.who.int/publications/i/item/9789240037656 Accessed: Oct 2024.
4. Cleveland LM, Minter ML, Cobb KA, Scott A, German VF. Lead hazards for pregnant women and children: Part 1. Am J Nurs 2008; 108:40–9. https://doi.org/10.1097/01.NAJ.0000337736.76730.66.
5. Yadav G, Chambial S, Agrawal N, Gothwal M, Kathuria P, Singh P, *et al.* Blood lead levels in antenatal women and its association with iron deficiency anemia and adverse pregnancy outcomes. J Family Med Prim Care 2020; 9:3106–11. https://doi.org/10.4103/jfmpc.jfmpc_78_20.
6. Ahamed M, Mehrotra PK, Kumar P, Siddiqui MK. Placental lead induced oxidative stress and preterm delivery. Environ Toxicol Pharmacol 2009; 27:70–4. https://doi.org/10.1016/j.etap.2008.08.013.
7. Oza S, Lawn JE, Hogan DR, Mathers C, Cousens SN. Neonatal cause-of-death estimates for the early and late neonatal periods for 194 countries: 2000–2013. Bull World Health Organ 2015; 93:19–28. https://doi.org/10.2471/BLT.14.139790.
8. Rodosthenous RS, Burris HH, Svensson K, Amarasiriwardena CJ, Cantoral A, Schnaas L, *et al.* Prenatal lead exposure and fetal growth: Smaller infants have heightened susceptibility. Environ Int 2017; 99: 228–33. https://doi.org/10.1016/j.envint.2016.11.023.
9. Nishioka E, Yokoyama K, Matsukawa T, Vigeh M, Hirayama S, Ueno T, *et al.* Evidence that birth weight is decreased by maternal lead levels below 5 μg/dl in male newborns. Reprod Toxicol 2014; 47:21–6. https://doi.org/10.1016/j.reprotox.2014.05.007.
10. Moussaoui F, Demmouche A. Relation between low birth weight and maternal blood lead levels in Sidi Bel Abbes, Algeria: A case-control study. Journal of Drug Delivery and Therapeutics 2020; 10:115–19. https://doi.org/10.22270/jddt.v10i2-s.4023.
11. CDC. Advisory Committee on Childhood Lead Poisoning Prevention. CDC updates blood lead reference value for children low level lead exposure. From: https://www.cdc.gov/media/releases/2021/p1028-blood-lead.html Accessed: Oct 2023.
12. Mohammad LM, Karami M, Mehrabi Y, Nazari SS, Dehghan SF, Baiee H, *et al.* Investigating blood lead levels and its health effects on employees of a petroleum industry and the surrounding residents: A case study of Kirkuk City-Iraq. J Occup Environ Med 2024; 66:924–31. https://doi.org/10.1097/JOM.0000000000003199.
13. Al-Rudainy LA. Blood lead level among fuel station workers. Oman Med J 2010; 25:208–11. https://doi.org/10.5001/omj.2010.58.
14. Altaay LMM, AL-Sarray AH, Hasson SM. Blood lead level among a sample of Iraqi workers in Baghdad city. World J Pharm Res 2018; 7:1367–76. https://doi.org/10.20959/wjpr20189-10109.
15. Ajeel NAH, Alrudainy LA, Al-Yassen AK. Blood lead level among children in Basrah. The Med J Basrah Uni 2007; 25:7–10. https://doi.org/10.33762/MJBU.2007.48117.
16. Al Naama LM, Hassan MK, Hehdi JK, Al Sadoon IO. Screening for blood lead levels in Basrah, Southern Iraq. Qatar Med J 2010; 19:43–7. https://doi.org/10.5339/qmj.2010.2.15
17. Ruckart PZ, Jones RL, Courtney JG, LeBlanc TT, Jackson W, Karwowski MP, *et al.* Update of the blood lead reference value - United States, 2021. MMWR Morb Mortal Wkly Rep 2021; 70:1509–12. https://doi.org/10.15585/mmwr.mm7043a4.
18. Centers for Disease Control and Prevention (CDC). Adult blood lead epidemiology and surveillance-United States, 2008-2009. MMWR Morb Mortal Wkly Rep 2011; 60:841–5.
19. Pagana KD, Pagana TJ, Pagana TN. Mosby's Diagnostic and Laboratory Test Reference, 14th ed. St. Louis, Missouri, USA: Elsevier, 2018.
20. Raj K, Das AP. Lead pollution: Impact on environment and human health and approach for a sustainable solution. Environ Chem Ecotoxicol 2023; 5:79–85. https://doi.org/10.1016/j.enceco.2023.02.001.
21. Al-Jawadi AA, Al-Mola ZW, Al-Jomard RA. Determinants of maternal and umbilical blood lead levels: a cross-sectional study, Mosul, Iraq. BMC Res Notes 2009; 2:47. https://doi.org/10.1186/1756-0500-2-47.

22. Sahb AA, Khudhair SY, Al-Yasseri BJ. Association of maternal blood lead levels with newborns birth weights. Int J Adv Res 2016; 4:202–11. https://doi.org/10.21474/IJAR01/2072.
23. Dalili H, Shariat M, Kavyani Z, Fazel M, Raji F, Jamali F, *et al.* Correlation between lead in maternal blood, umbilical cord blood, and breast milk with newborn Anthro-pometric characteristics. Iranian J Neonatol 2019; 10:6–11. https://doi.org/10.22038/ijn.2019.38763.1610.
24. Ladele JI, Fajolu IB, Ezeaka VC. Determination of lead levels in maternal and umbilical cord blood at birth at the Lagos University Teaching Hospital, Lagos. PLoS One 14:e0211535. https://doi.org/10.1371/journal.pone.0211535.
25. Mahdi AA, Ansari JA, Chaurasia P, Ahmad MK, Kunwar S, McClean S, *et al.* A study of maternal and umbilical cord blood lead levels in pregnant women. Indian J Clin Biochem 2023; 38:94–101. https://doi.org/10.1007/s12291-022-01040-0.
26. Reddy YS, Aparna Y, Ramalaksmi BA, Kumar BD. Lead and trace element levels in placenta, maternal and cord blood: A cross-sectional pilot study. J Obstet Gynaecol Res 2014; 40:2184–90. https://doi.org/10.1111/jog.12469.
27. Harville EW, Hertz-Picciotto I, Schramm M, Watt-Morse M, Chantala K, Osterloh J, *et al.* Factors influencing the difference between maternal and cord blood lead. Occup Environ Med 2005; 62:263–9. https://doi.org/10.1136/oem.2003.012492.
28. El Khaleegy HA, Abo Baraka WE, El-moghazy MK. Study of umbilical blood lead level and its relation with pregnancy outcome. J Med Pharm Sci 2019; 3:56–68. https://doi.org/10.26389/AJSRP.W040319.
29. Shih-Huia H, Ken-Pen W, Ching-Chiang L, Chung-Cheng W, Tzu-Chi LC, Luo-Ping G, *et al.* Maternal and umbilical cord blood levels of mercury, manganese, iron, and copper in southern Taiwan: A cross-sectional study. J Chinese Med Assoc 2017; 80:442–51. https://doi.org/10.1016/j.jcma.2016.06.007.
30. Shukla AK, Srivastava S, Verma G. Effect of maternal anemia on the status of iron stores in infants: A cohort study. J Family Community Med 2019; 26:118–22. https://doi.org/10.4103/jfcm.JFCM_115_18.
31. Arshad S, Arif A, Wattoo JI. Response of iron deficiency markers to blood lead levels and synergistic outcomes at prenatal stage. Dose Response 2022; 20:15593258221101744. https://doi.org/10.1177/15593258221101744.
32. Torabi Z, Halvachi M, Mohseni M, Khederlou H. The relationship between maternal and neonatal umbilical cord blood lead levels and their correlation with neonatal anthropometric indices. J Comprehensive Pediatr 2018; 9:e55056. https://doi.org/10.5812/compreped.55056.
33. Neda AN, Fahimeh S, Tahereh ZK, Leila F, Zahra N, Bahman C, *et al.* Lead level in umbilical cord blood and its effects on newborns anthropometry. J Clin Diagn Res 2017; 11:SC01–SC04. https://doi.org/10.7860/JCDR/2017/24865.10016.