A Study of Maternal and Umbilical Cord Blood Lead Levels in Pregnant Women

Mahdi, A. A., Ansari, J. A., Chaurasiaa, P., Ahmad, M. K., Kunwar, S., McClean, S. I., & Yogarajah, P. (2022). A Study of Maternal and Umbilical Cord Blood Lead Levels in Pregnant Women. *Indian Journal of Clinical Biochemistry*, *38*(1), 94-101. [1040]. https://doi.org/10.1007/s12291-022-01040-0

Link to publication record in Ulster University Research Portal

Published in:
Indian Journal of Clinical Biochemistry

Publication Status:
Published online: 22/06/2022

DOI:
10.1007/s12291-022-01040-0

Document Version
Author Accepted version

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Article Sub-Title		
Article CopyRight	The Author(s), under exclusive licence to Association of Clinical Biochemists of India (This will be the copyright line in the final PDF)	
Journal Name	Indian Journal of Clinical Biochemistry	
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Schedule	Received	3 Jul 2021
	Revised	
	Accepted	30 Mar 2022

Abstract

Lead is a highly toxic element which can cross the placental barrier and enter the fetus during pregnancy. Parental lead exposure has adverse effect on infant as well as on maternal health. As part of our program to investigate the lead poisoning in human population we investigated the maternal blood lead levels (MBLL) and umbilical cord blood lead (UBLL) levels in 200 pregnant women and collected their socio-demographic details. In the study we found high lead levels in both maternal and umbilical cord blood samples. The results showed 47.5% maternal blood ($n = 95$) detected with lead while 38.5% umbilical cord blood ($n = 77$) samples had lead concentration higher than that of reference range of ≤ 5 μg/dL. We also found that the Spearman's correlation coefficient (rs) revealed a strong positive correlation between the MBLL and UBLL (rs = 0.63). The results from socio-demographic questionnaire demonstrated that the recent home painting ($p = 0.002$) and residing close proximity to traffic congestion ($p = 0.05$) were significantly associated with MBLL. Education, mother age, fuel and water sources were not significantly associated with MBLL. Iron and calcium deficiency along with tiredness, lethargy, abdominal pain were also reported in women having high lead level > 5 μg/dL. Concludingly, on the basis of results obtained it may be stated that we found elevated BLLS in both pregnant women as well as in umbilical cord blood. The prevalence of elevated lead levels in mothers will expose the fetus to lead through placental barriers mobilization and it can have long term adverse effects on the developing fetus. Therefore, it is recommended that screening of blood lead levels be carried out in high-risk women based on their social, occupational, environmental, and individual factors. In addition, stringent regulations on lead-based products are also required from government agencies/authorities to reduce environmental lead burden and toxicity. Moreover, public awareness programs should be organized on hazardous effect of lead toxicity.

Keywords (separated by '-') Maternal blood lead level - Umbilical cord blood lead level - Socio demographic details - Lead poisoning

Footnote Information

Ind J Clin Biochem
https://doi.org/10.1007/s12291-022-01040-0

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ORIGINAL RESEARCH ARTICLE

A Study of Maternal and Umbilical Cord Blood Lead Levels in Pregnant Women

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Received: 3 July 2021 / Accepted: 30 March 2022
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Abstract Lead is a highly toxic element which can cross the placental barrier and enter the fetus during pregnancy. Parental lead exposure has adverse effect on infant as well as on maternal health. As part of our program to investigate the lead poisoning in human population we investigated the maternal blood lead levels (MBLL) and umbilical cord blood lead (UBLL) levels in 200 pregnant women and collected their socio-demographic details. In the study we found high lead levels in both maternal and umbilical cord blood samples. The results showed 47.5% maternal blood (n = 95) detected with lead while 38.5% umbilical cord blood (n = 77) samples had lead concentration higher than that of reference range of $\leq$ 5 µg/dL. We also found that the Spearman's correlation coefficient (rs) revealed a strong positive correlation between the MBLL and UBLL (rs = 0.63). The results from socio-demographic questionnaire demonstrated that the recent home painting (p = 0.002) and residing close proximity to traffic congestion (p = 0.05) were significantly associated with MBLL. Education, mother age, fuel and water sources were not significantly associated with MBLL. Iron and calcium deficiency along with tiredness, lethargy, abdominal pain were also reported in women having high lead level > 5 µg/dL. Concludingly, on the basis of results obtained it may be stated that we found elevated BLLS in both pregnant women as well as in umbilical cord blood. The prevalence of elevated lead levels in mothers will expose the fetus to lead through placental barriers mobilization and it can have long term adverse effects on the developing fetus. Therefore, it is recommended that screening of blood lead levels be carried out in high-risk women based on their social, occupational, environmental, and individual factors. In addition, stringent regulations on lead-based products are also required from government agencies/authorities to reduce environmental lead burden and toxicity. Moreover, public awareness programs should be organized on hazardous effect of lead toxicity.

Keywords Maternal blood lead level · Umbilical cord blood lead level · Socio demographic details · Lead poisoning

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Introduction

Lead, an environmental toxicant which accounts for 0.6% of the global burden of disease, with the highest burden in developing countries like India [1]. Even though several attempts have been made and regulatory authorities are working globally to reduce environmental lead contamination, yet, lead poisoning and exposure still remains a major public health concern. People get exposed to lead unknowingly and they may suffer from lead-related complications without being aware of it. Pregnant women and children are most vulnerable to this exposure. Studies on the effect of lead exposure on women health and pregnancy outcomes are seriously advocated [2]. Long-term (chronic)

Journal : Large 12291 | Dispatch : 20-4-2022 | Pages : 8
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MS Code : IJCB-D-21-00213R1 | ☑ CP | ☑ DISK

lead exposure has been documented as a cause of disruption in the fetal developmental process and pregnancy outcome [3]. There are reports that maternal blood lead levels are on an average about 30% higher than that of the infants in most studies and approximately one quarter of infants have blood lead level higher than their mothers [4]. The severity of outcomes of lead toxicity may fluctuate significantly from country to country.

Lead can permeate through the placental as well as blood-brain barrier via passive diffusion and causes negative impact on fetal growth and the developing brain [5]. Lead has been detected in the fetal brain as early as in the 13th week of gestation [6] and causes adverse pregnancy outcomes including gestational hypertension [7], preterm delivery [8], neurological complications [9], congenital anomalies, [10] low birth weight,[11] decreased length and head circumference [12]. Some of the worst effects of lead poisoning are miscarriage and stillbirths [13, 14].

Lead had been detected in blood samples of children, pregnant women, battery workers and painters above the permissible limit in many developing countries including India [15, 16]. Moreover, high lead contamination in soil [17], water [18], air [19], herbal products [20], lead acid batteries [21], paints [22], cosmetics mainly (Kohl, lipsticks sindoor, hair dye) [23], and utensils have been reported [24].

Although the lead poisoning is a serious health hazard, however, unfortunately there are currently no internationally recognized guidelines on the prevention and management of lead poisoning. Although, some countries have their own regulatory protocols to control lead poisoning [15, 25]. In the absence of effective screening and exposure prevention program, lead poisoning cases are particularly arduous at certain places and it results in huge health and economic burden on society, particularly for pregnant women and prenatal fetus. In the present study we have studied maternal blood lead levels and umbilical cord blood lead levels of 200 pregnant women. Moreover, the study also evaluated socio-demographic details along with other nonspecific parameters associated with lead poisoning.

Materials and Methods

Collection of Blood Samples

Pregnant women visiting Era's Lucknow Medical College and Hospital, Lucknow, (India), for delivery were explained the significance, need, and design of the study. An informed, written consent was obtained from the subjects volunteering to take part in the study. In the study 200 mother blood samples and 200 umbilical cord blood samples were taken.

For the estimation of Blood Lead Levels (BLL), 2 ml of venous blood and 2 ml of the umbilical cord blood were collected in Ethylene diamine tetra-acetic acid (EDTA) vaccutainers, labeled and kept in cooling box unless analyzed.

Questionnaire and Observations

The study was approved by the Institutional Ethics Committee, Era's Lucknow Medical College & Hospital, Lucknow (ELMC/R_Cell/EC/2018/83). A questionnaire form used in the study included socio-demographic features (age, gestation period, education, residential location, source of drinking water, occupational exposure) indicating possibility of lead exposure. AQ1

Inclusion and Exclusion Criteria

The normal pregnant women visiting Era's Lucknow Medical College and Hospital, Lucknow, (India), for delivery were included in the study. Previously known lead exposed and lead poisoning cases were excluded from the study.

Analysis of Lead

Analysis of blood lead level was performed by method described by Ansari et al. [26] with little modifications. The blood samples were digested by a microwave reaction system and analyzed with the help of an ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrophotometer, Optima 8000, Perkin Elmer, USA). The calibration standard for ICP-OES was prepared by diluting the stock standard solution (1000 mg/L) of Pb in 0.2% (v/v) nitric acid. Working solutions was prepared from the stock as necessary. The calibration curve for Pb was prepared by different concentrations of standard in the range 0.005–1.0 mg/L from working solution. The blood lead level result was expressed in µg/dL. AQ2

Biochemical Analysis

The biochemical parameters. Serum Iron (Fe) and Calcium (Ca) were analyzed on fully automatic bi analyzer (Vitros 350, Dry Chemistry Analyzer, Ortho Clinical Diagnostics, USA, Cobas E411, Roche,USA). AQ3

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Statistical Analysis

Data was analyzed using the Statistical Package for the Social Sciences (SPSS). Data was reported as mean ± SD. Spearman's correlation coefficient (rs) was used to demonstrate correlation between the maternal blood lead levels. The level of statistical significance was set at $p < 0.05$ (Fig. 1).

Results

Blood Lead Levels (BLLs)

Descriptive lead levels and relationship between the maternal and umbilical cord blood is presented in Table 1. The studied maternal and umbilical cord subjects were categorized into ND (Not Detected), 0–5, 5–20 and > 20 µg/dL groups based on lead level detected in the samples. We found that amongst the 200 studied subjects of maternal blood, 59.5% samples had BLL with a mean value of 10.41 µg/dL ± 6.36, while 40.5% maternal blood had not detected with any lead concentration. Similarly, amongst the 200 samples of umbilical cord blood, 43% of the samples were not having any lead concentration while in 57% samples BLL had a mean value of 10.73 ± 8.27 µg/dL. The relationship between mother blood lead level (MBLL) and umbilical cord blood lead level (UBLL) showed a positive correlation between above two variables with a significant coefficient of correlation (rs = 0.63, p = 0.000).

Maternal Socio-Demographic Characteristics and Risk Factors for Lead Exposure

In our study we used a questionnaire form to fetch the socio-demographic details including education, occupational exposure, clinical features, residence from traffic congestion, source of drinking water etc. On the analysis of questionnaire data, we found that a total of 10% (n = 19) mothers out of the studied (n = 200) subjects had complaints of lethargy and 9% (n = 18) reported tiredness and 7.5% (n = 13) had the problem of headache. Further exploration of above data revealed that the amongst the 10% subjects who reported lethargy, 26% (n = 5) of them had lead level in range between 5 and 20 µg/dL. Moreover, amongst the 9% subjects with tiredness complaint, 56% (n = 10) of them had lead level in range 5 to 20 µg/dL. Seven and half percent (n = 13) subjects with headache complaint, 62% (n = 8) amongst them had lead level 5–20 µg/dL. Taken overall, these manifestations of elevated lead level in subjects warranted the possible lead toxicity.

Biochemical investigations showed that amongst the studied subjects 10% (n = 20) had iron deficiency and amongst this 70% (n = 14) had lead level in the range 5–20 µg/dL and 25% (n = 5) had lead level above 20 µg/dL. Additionally, 11% (n = 6) subjects had calcium deficiency and amongst this 90% (n = 10) subjects had lead level in the range between 5 and 20 µg/dL. We also found that in the studied 200 maternal subjects, 2% (n = 4), 7% (n = 13) and 1% (n = 2) subjects had complaint of anorexia, abdominal pain and constipation, respectively (Table 2).

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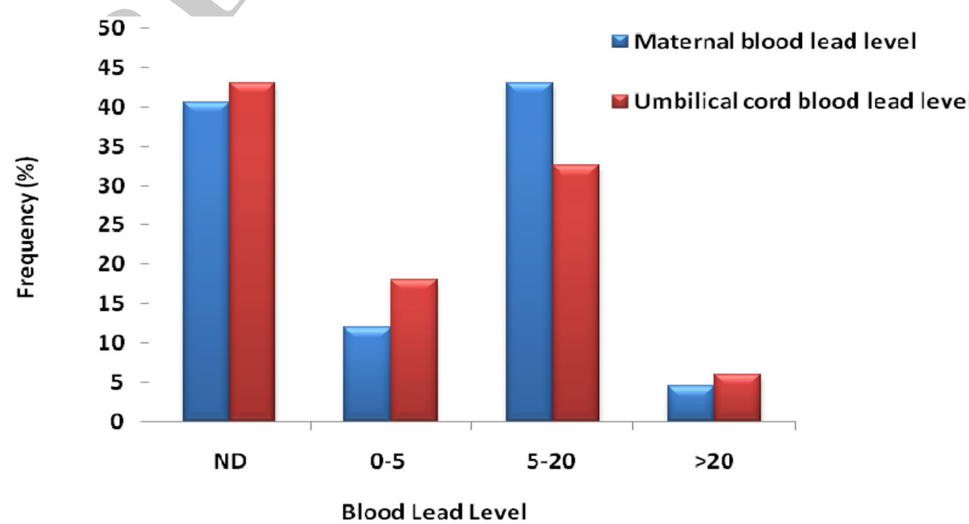

Fig. 1 Distribution of lead levels in maternal and umbilical cord blood. (Blood lead level in µg/dL, *ND* not detected)

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Table 1 Maternal and umbilical cord blood level

Sample	Mean blood lead levels				
Maternal blood (n = 200)	ND (n = 81) (40.5%)	(n = 119) (59.5%)			ND-34.8 µg/dL (n = 200)
		0–5 µg/dL (n = 24) (12%)	5–20 µg/dL (n = 86) (43%)	> 20 µg/dL (n = 9) (4.5%)	
Mean	ND	4.06	10.73	24.73	10.41
SD	ND	0.64	4.61	5.96	6.36
Umbilical cord blood (n = 200)	ND (n = 86) (43%)	(n = 114) (57%)			ND-45 µg/dL (n = 200)
		0–5 µg/dL (n = 36) (18%)	5–20 µg/dL (n = 65) (32.5%)	> 20 µg/dL (n = 13) (6.5%)	
Mean	ND	3.66	11.12	28.36	10.73
SD	ND	0.61	4.24	7.71	8.27

ND Not detected, *SD* standard deviation

Table 2 Different clinical symptom as reported by mothers

Symptoms	ND (n = 81) (%)	0–5 µg/dL (n = 24) (%)	5–20 µg/dL (n = 86) (%)	> 20 µg/dL (n = 9) (%)	n = 200
Non-specific					
Lethargy	14 (17)	0 (0)	5 (6)	0 (0)	19 (9)
Tiredness	6 (7)	2 (8)	10 (12)	0 (0)	18 (9)
Headache	3 (3)	0 (0)	8 (9)	2 (22)	13 (7.5)
Gastro-intestinal					
Anorexia	1 (1)	0 (0)	3 (3)	0 (0)	4 (2)
Abdominal pain	1 (1)	0 (0)	9 (10)	2 (22)	13 (7)
Constipation	1 (1)	0 (0)	1 (1)	0 (0)	2 (1)
Pica symptom					
Iron deficiency	1 (1)	0 (0)	14 (16)	5 (56)	20 (10)
Calcium deficiency	1 (1)	0 (0)	10 (12)	0 (0)	11 (5.5)

The obstetrics features of the studied pregnant women showed that the mean gestational age and birth weight were 38.2 ± 2.44 weeks and 2.80 ± 0.5 kg, respectively. We found that 17% subjects had gestation age below 37 weeks, 78% had in between 37 and 41 weeks and 5% had > 41 weeks. Moreover, around 18% birth weights were ranged between 1500 and 2499 g while 81.5% were 2500 to 4000 g and rests were below 1500 g (Table 3). Furthermore, the age of the pregnant women detected with lead (n = 119) and without lead (n = 81) were found to be 28.6 ± 3.41 years and 28.5 ± 3.27 years, respectively.

In the present study we also attempted to evaluate the socio demographic details of the studied subjects. For this, the studied subjects were asked about their education, occupation, demographic attributes including water sources, utensil, fuel source, housing, paint etc. Depicted in Table 3, the pregnant women detected with lead (n = 119), 94% of them were residing more than 3 years at the present place and 5.8% were residing less than 3 years at their present place. We recorded a higher proportion of elevated lead samples in mother who had lived in their present place of more than three year. However, we did not find

Table 3 Gestational age and socio-demographic study of participants

Variables	n = 200, n (%)
Gestational age (weeks)	
< 37 weeks	34 (17)
37–41 weeks	156 (78)
> 41 weeks	10 (5)
Mean ± SD (weeks)	38.2 ± 2.44
Birth weight (g)	
< 1000	2 (1)
1000–1499	3 (1.5)
1500–2499	35 (17.5)
2500–4000	163 (81. 5)
Mean ± SD (g)	2.80 ± 0.5

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statistically significant correlation of residence and pregnant women with elevated lead level. Moreover, most of the mothers were housewives and not correlated with elevated lead level. Additionally, education did not have any statistically significant effect on the concentration of lead in the mothers.

Paint has been a possible source of lead toxicity and we observed that a large percentage of elevated lead samples in pregnant women who had their home painting less than one year. It has been found that around 75.6% pregnant subjects lived at the present place had their home painting/renovation less than one year while 24.3% had home painting more than one year. We have found statistically significant correlation ($p = 0.002$) of recent painting (< 1 year) with elevated lead samples of pregnant women.

The leaded gasoline use and vehicular emissions from heavy traffic is also a contributing factor for lead exposure. We observed that 39.4% mothers were residing in close proximity to major roads/traffic congestion less than 2 km and 60.5% were residing more than 2 km from traffic congestion. The proximity of residence to a major traffic congestion was significantly associated with the women with elevated lead level ($p = 0.05$). Contaminated drinking water is well known to various adverse effect and toxicity on human. However, we have not found any significant correlation of elevated lead level in pregnant women with drinking water. Almost all the cases were reported to use LPG as fuel source. The detailed questionnaire is summarized in Table 3.

Relationship between Maternal Blood Lead Levels with Socio-Demographic Factors

Variables ($n = 200$)	Maternal blood with lead levels positive ($n = 119$) n (%)	Maternal blood with lead levels negative ($n = 81$) n (%)	Statics	p-Value
Mother's age (Years)				
< 25 (17)	8 (6.7)	9 (11.1)	$\chi^2 = 1.2$	0.737
25–30 (133)	81 (68.0)	52 (64.1)		
31–35 (47)	28 (23.5)	19 (23.4)		
> 35 (3)	2 (1.6)	1 (1.2)		
Mean ± SD (years)	28.6 ± 3.41	28.5 ± 3.27	$t = 0.44$#	
Educational level				
None (4)	3(2.5)	1()	$\chi^2 = 1.2$	0.890
≤ 10 (34)	21 (17.6)	13(16.0)		
Intermediate (60)	33 (27.7)	27 (33.3)		
Graduation (78)	48 (40.3)	30 (37.0)		
Post graduate (23)	14(11.7)	9(11.11)		
>PG (1)	0(0)	1(1.2)	$t = 0.6$	
Positive maternal occupational exposure				
Housewife (191)	117 (98.3)	74 (91.4)		
Working (9)	2 (1.7)	7 (8.6)	$t = 0.28$	0.80
No. of years in present Residence				
Residence < 3 year (10)	7 (5.8)	3 (3.7)	$\chi^2 = 0.48$	0.487
> 3 Years (190)	112 (94.1)	78 (96.2)	$t = 0.29$	
Recent Home painting				
Home painting (≤ 1 year) (65)	29 (24.3)	36 (44.4)	$\chi^2 = 8.8$	0.002*
>I years (135)	90 (75.63)	45 (55.5)	$t = 0.61$	
Location of residence from traffic congestion/major roads				
Traffic congestion (≤ 2 km) (90)	47 (39.4)	43 (53.0)	$\chi^2 = 3.59$	0.057*
> 2 km (110)	72 (60.5)	38 (46.9)	$t = 1.49$	
Source of drinking water				
Borehole (48)	27 (22.6)	21 (25.9)	$\chi^2 = 0.61$	0.733
RO/bottle water (83)	52 (43.6)	31 (38.2)		
Public supply (69)	40 (33.6)	29 (35.8)	$t = 1.61$	
Fuel source				
LPG (200)	119 (59.5)	81 (40.5)	$t = 0.26$	0.760
Other sources (kerosene, wood, coal etc.) (0)	0 (0)	0 (0)		

#Student t test, χ^2 Chi square test

*Statistically significant

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Discussion

The present study demonstrated elevated blood lead levels in maternal and umbilical cord blood samples. The mean BLLs in pregnant women were found to be 10.41 ± 6.36 µg/dL (range of 2.3–34.8 µg/dL, $n = 119$). This showed that 59.5% of the mothers from studied two hundred subjects had high lead concentration in their blood. It was also observed that 47.5% ($n = 95$) of maternal blood had higher lead levels than the reference range of ≤ 5 µg/dL as specified by CDC [27]. The results of our study are in concordance with the previous study carried out by Srivastava et al., who reported the mean BLLs 10.29 ± 5.69 µg/dL in maternal blood samples from Lucknow region. They have also shown that among the studied maternal samples 53% mothers had blood Pb level > 10 µg /dL, 34% had 10–20 µg/dL, 17% had 20.1–30 µg/dL, and 2% had > 30 µg/dL [28]. Overall, our findings are in agreement with the above study and imitate the lead toxicity in Lucknow region. In another study carried out in pregnant women from Lucknow and nearby areas by Awasthi et al., 2002, they have shown elevated maternal blood lead level 14.6 ± 7.9 µg/dL, 14.5 ± 8.0 µg/dL and 14.1 ± 7.6 µg/dL, during first, second and third trimesters, respectively. Moreover, they also showed that the mean BLLs in women living in the inner city ($n = 197$) were the highest value of 15.7 ± 8.2 µg/dL [29]. Furthermore, the study carried out by Saxena et al., 1994 reported that the mean maternal blood lead level was 19.4 µg/dL in normal delivery group; in explanation they have shown that 83% of the cases had BLLs ≤ 25 µg/dL, 13.6% had 26–35 µg/dL, the remaining cases had > 35 µg/dL [30]. Taken together, all these studies are in support with our findings and showed that the elevated mother blood lead level unconditionally attributed lead toxicity to mothers as well as to the developing fetus too.

As far as studies related to umbilical cord blood samples are concerned the mean lead level was found to be 10.73 ± 8.27 µg/dL (range of 2.1–45 µg/dL) ($n = 114$). This mean value of lead in umbilical cord was also high than that of reference range of ≤ 5 µg/dl. There has been a report from Lucknow region which has shown that the mean lead level in umbilical cord blood was 11.40 + 5.85 µg/dL. Moreover, it has also shown that 54% infants had cord blood lead level > 10 µg/dL, 28% had 10–20 µg/dL, 17% had 20.1–30 µg/dL, and 9% had > 30 µg/dL [28]. In another study, the mean cord blood lead level in the normal delivery groups was reported to be 16.96 µg/dL with 83% samples had lead level ≤ 25 µg/dL and 17% had lead level > 25 µg/dL [30]. These findings are in concurrence with our results demonstrating elevated umbilical cord blood lead levels which may be transported to fetus. These findings, in pregnant women warrants for possible implication of high risk of severe health effects on the off-springs. The high lead level in mother is likely due to higher level of lead contamination in environment mainly in the Lucknow city and nearby areas [31]. There are several factors such as vehicles, informal recycling lead battery workshops, widespread constructions, lead based paints and particulate matters from various man-made activities which may account for the higher degree of lead contamination [32].

The present study showed that the mean lead level in umbilical cord blood was high and this is a reflection of mother blood lead concentration. There are reports of high level of lead in maternal blood samples, children, and other battery workshop workers in developing countries especially in India in contrast to developed countries where there is ban on leaded gasoline, lead based paints and herbal products since they have implemented bio monitoring and several regulatory strategies to control and reduce the environmental lead load [33, 34].

The present study demonstrated that there was a strong positive correlation between MBLL and UBLL level (rs = 0.63, $p = 0.000$). This assumes that maternal blood lead level may be a suitable marker of prenatal lead exposure. There have been studies which have shown that there was a direct relationship between maternal and umbilical cord lead level [35]. Moreover, it has been also illustrated that the higher lead levels were found in maternal samples when compared with the umbilical cord blood level [35–37]. In contrast, we have observed in our study that some percent of umbilical cord samples had higher lead level than the counterpart of their mother samples. This contrasting results accentuate that further studies should be carried out to explore the possible factors which may responsible for this variance.

The clinical manifestations, revealed through the questionnaire, of lethargy, tiredness and headache were observed in the mothers who had elevated blood lead levels, however, mothers with no lead level also reported these symptoms but to a lesser extent. The gastro-intestinal features such as anorexia, abdominal pain and constipation were found less in mothers who had no lead in blood, however, mothers who had high blood lead levels reported these symptoms more frequently. Earlier, it was reported that chronic lead exposure leads to recurrent abdominal pain, nausea, vomiting, constipation, bloating, anorexia and weight loss [38–41]. In the present study we found gastrointestinal manifestations of lead poisoning more in mothers who had lead level in the range of 5–20 µg/dl.

The role of calcium and iron and their importance in pregnancy is quite well known. The findings of the present study revealed that about 10% pregnant women who had blood lead levels between 5 and 20 µg/dL) had calcium

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deficiency. Calcium supplementation is recommended during pregnancy mainly in third trimester and during lactation due to high demand to fetus. It may be pointed out here that lead competes with calcium [42] and therefore calcium supplementation may play an important role in reducing MBLLs in pregnant women. It may be mentioned here that we also found that pregnant women were also iron deficient (having BLL 5–20 and > 20 µg/dL, respectively). Cohen et al., reported that lead poisoning causes anaemia as lead inhibits porphobilinogen synthase and ferrochelatase, preventing both porphobilinogen formation and the incorporation of iron into protoporphyrin IX, which prevents heme synthesis [43]. Iron deficiency along with diminished heme synthesis may lead to more anemia related complications. In a recent study we also reported that children with high BLLs had low hemoglobin [44]. Calcium and iron are essential elements and regulate various biochemical and biophysical processes in the body. Deficiencies of these elements may comprehensively increase the absorption of lead in the body [45]. There are reports that calcium and iron in association with zinc and magnesium play important roles in various biological metabolisms such as neurocognitive functions, inflammation, CVD, febrile etc. [46, 47]. There is a report of CDC recommending adequate dietary intake of calcium and iron to prevent lead toxicity [48].

Conclusions

The present results highlighted the prevalence of elevated lead levels in maternal and umbilical cord blood samples. The study eventually affixed evidence of high blood lead concentration in Lucknow city and nearby areas. The positive significant coefficient between maternal blood and cord blood warranted the possible lead exposure and mobilization to the developing fetus.

The socio-demographic study highlighted that recent painting/renovation and close proximity to traffic congestion/major roads are significantly associated with high lead level in pregnant women. Therefore, an urgent need is obligatory from the regulatory authorities to draft and enforce policies on the manufacture, sale and distribution of lead based products to reduce lead burden. There is also a need to create awareness in public and society on the perilous effect of lead toxicity.

Acknowledgements The research outlined here was supported by Department of Economy, Northern Ireland, UK under the Global Challenge Research Fund grants through Ulster University, UK and InSLAR (Indian Society for Lead Awareness and Research) for their financial support of the present study.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

Informed Consent Written consent was obtained from the patients for publication of this study.

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