Hematologic Profile of Battery Repair Workers Occupationally Exposed to Lead in Lagos, Nigeria

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Abstract

Background: Lead is one of ten chemicals of key public health concern. It inhibits various enzymes in the synthesis and homeostasis of red blood cells, hence altering hematologic parameters in those chronically exposed. **Aim:** This study aims to assess the degree of lead exposure among battery lead repair workers in Lagos and relate it to their hematologic profile. **Materials and Methods:** Structured interviewer-administered questionnaires were used to record demographic data. Blood samples were taken to determine full blood count, erythrocyte protoporphyrin, serum ferritin, and blood lead levels (BLL). BLLs were determined by atomic absorption spectrometry. BLL were categorized as mild, moderate, or severe and were related to hematologic parameters. Categorical data were presented as proportion and continuous data as means or median. The effects of personal protective equipment on BLLs were assessed. **Results:** A total of 66 men with the mean age 46.15 ± 11.73 years and average duration of exposure to lead of 23.33 ± 11.03 years were enrolled. The median BLL was 20.75 µg/l (interquartile range). Majority had BLL between 20 and 40 µg/l, 4.55% had severely elevated lead levels. Participants with >30 years of exposure had a higher BLL ($P = 0.046$). BLL was negatively correlated with RBC count ($r = -0.322$ $P = 0.008$) and positively correlated with mean cell volume (MCV) ($r = 0.277$ $P = 0.025$). Mean MCV was 86.39 fl ± 7.90 fl). Participants with BLL >40 µg/l had higher MCV ($P = 0.038$). **Conclusion:** Battery repair workers have moderate exposure to lead which is not enough to lead to significant hematologic effect.

Keywords: Battery repair workers, blood lead, haematologic profile

Introduction

The toxicity of lead has been documented as early as 2000 BC, and its exposure is arguably the oldest known occupational health hazard.[1,2] It has no role to play in the healthy functioning of the human body; however, its good electrochemical and mechanical properties has led to its wide use in daily life, especially in industries.[3] At present, the consumption of lead far outweighs the total consumption in all previous era and lead poisoning now accounts for 0.6% of global burden of disease.[4] Despite the fact that lead poisoning is entirely preventable, the World Health Organization has identified it as 1 of 10 chemicals of major public health concern.[5]

The battery industry is the largest consumer of lead, using an estimated 80% of the global lead production and 50% of global lead production is derived from recycling lead batteries.[6,7] Airborne lead concentrations reported in battery plants in developing countries averaged 367 µg/m^3, which is 7-fold greater than the US Occupational Safety and Health Administration's 50 µg/m^3 permissible exposure limit.[6] Battery recycling is an important source of exposure to inorganic lead vapors, particles, and debris.[8] In the unorganized setup, exposure to lead is highest among those who recycle and charge batteries and lowest among those who charge only.[7]

Battery repair workers popularly known in Nigeria as "battery chargers (BRW)" are usually involved in dismantling disused batteries, washing lead cells in water, and smelting the cells, and hence by the nature of work assumed to be moderately

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exposed to lead. Lead intoxication has been reported in 40% of lead–acid battery workers in Nigeria as far as 1971.[9]

The onset of clinical lead intoxication is usually insidious and is associated with moderately elevated blood lead levels (BLL) over 20 μg/dl; however, recent evidence does suggest that no level of lead exposure is actually safe.[7] One of the key system often affected in lead poisoning is the hemopoietic system. The major mechanism through which lead causes anemia is through the inhibition of the various enzymes involved the synthesis of hemoglobin.[3] Intramitochondrial enzyme ferrochelatase is responsible for the chelation of iron (Fe) by protoporphyrin. Failure to insert Fe into the protoporphyrin ring results in depressed hem formation and an accumulation of protoporphyrin; this in turn chelates zinc in place of Fe, to form zinc protoporphyrin (ZP).[1,3,10]

Lead is also a potent inhibitor of pyrimidine 5'-nucleotidase, Type 1, an enzyme involved in the catabolism of ribonucleic acid from young red blood cells (RBCs) (reticulocytes). It has a high affinity to pyrimidine monophosphates (uridine and cytidine monophosphates). Pyrimidine 5' nucleotidase is responsible for dephosphorylation of pyrimidine 5'-monophosphate to nucleosides which diffuses out of the cell. Its inhibition by lead hence leads to a lead (Pb)-induced hemloysis and may explain the basophilic stippling seen in Pb poisoning. The anemia is usually normocytic normochromic or slightly hypochromic. Basophilic stippling is characteristic but not a universal finding. Blood lead concentrations are currently regarded as the most reliable index of exposure to lead.

Adverse health effects of lead have been observed even at levels as low as 10 μg/dl in children suggesting that there are no safe levels of exposure.[11,12] Therefore, this study was aimed at investigating lead exposure among lead–acid battery repair workers and describing the hematologic profile of these workers.

Materials and Methods

The study was a cross-sectional descriptive study carried out to determine the degree of lead exposure among lead battery repair workers at Mushin/Surulere Local Government Areas (LGA) of Lagos, Nigeria, using their BLL measured by atomic absorption spectrophotometer and to relate this to the hematologic profile of the battery repair workers.

Mushin and Surulere LGAs are both in Lagos mainland. Mushin LGA is located about 10 km from the core city center and is a densely populated area with low-quality housing. It is considered as part of Lagos metropolitan area while Surulere is a residential and commercial LGA also located on the mainland of Lagos state, Nigeria. It has a square area of 23 km^2. It has a population density of 21,864/km^2.

Eight different branches of the association of battery repair workers were identified in the two local governments. Each has an average of 25 members. Meetings are held weekly on Wednesdays. A purposive sampling technique was used. Participants were recruited from their branch meetings. Study units were drawn from all eight branches. Battery repair workers who had been working consistently for the past 1 year or more were enrolled. These workers were involved mainly in charging of batteries. Iron deficiency also leads to raised Elabscience erythrocyte protoporphyrin (EPP) levels, hence data from workers with serum ferritin level of <20 μg/dl were excluded during analysis.

Data about, age, work history, hours of daily lead exposure, duration of employments, protective measures adopted during work, and awareness about lead poisoning were obtained using a structured interviewer-administered questionnaire. The study protocol was approved by the Lagos University Teaching Hospital Health Research Ethics Committee, verbal permission was obtained from the branch chairmen of each branch, and informed written consent was obtained from each participant.

The interviews were conducted at the branch meetings of the association of battery repair workers which takes place once in a week, and during that time blood samples were collected. Each participant was given a serial number for easy identification. Standard operating procedure for phlebotomy was carefully followed in blood sample collection. Universal safety precautions were observed and strict confidentiality was maintained.

All the blood samples were drawn under aseptic conditions from the median cubital vein. About 5 ml of blood was collected from each participant; 3 ml of blood was collected into ethylenediaminetetraacetic acid anticoagulant bottle for analysis of BLL, and full blood count, while 2 ml of blood was collected into a plain bottle for serum ferritin analysis and erythrocyte protoporphyrin. Hematologic indices were determined by an automated analyzer (Sysmex KX 21N) on the same day. Separated serum was harvested and stored at −80°C till all samples were ready for estimation using the ELISA method. EPP ELISA and Calbiotech serum ferritin ELISA kit were used. The kits were used for the estimation of EPP and serum ferritin, respectively, while atomic absorption spectrophotometer was used for the estimation of blood lead.

The study participants were classified into 3 groups based on BLLs; those with mild BLL (<20 μg/dl), moderate BLL (20–40 μg/dl), and those with high BLL (>40 μg/dl) for further analysis. Anemia was defined as hemoglobin levels ≤13 g/dl.

Data obtained from the study were captured into a Spreadsheet, cleaned and analyzed using SPSS analytical tool version 21 (IBM SPSS Statistics Version 21, United States). Descriptive statistics were expressed as frequencies and percentages for categorical variable and mean ± standard deviation/ median (interquartile range [IQR]) for quantitative variables. Hematologic profiles were compared between the 3 BLL groups. The effect of use of personal protective equipment (PPE) on BLL was also assessed. Distribution of variables was checked using the Shapiro–Wilk test. Because of nonnormal distribution of parameters, the differences between mean values were tested using Mann–Whitney U-test. Pearson' correlation was applied to observe correlation between quantitative variables (blood indices and lead level). Correlation coefficient (r) was determined and $P \leq 0.05$ was considered as statistically significant.

Results

The demographic characteristics of the study population are presented in Table 1. All study participants were males and battery repair workers with mean age of 46.15 ± 11.73 years (range: 25–74 years). The mean number of years of exposure from place of work is 23.33 ± 11.03 years while the median hours at work per day was 8 h (IQR = 7–10 h). The median blood Pb level and EPP were 20.75 µg/dl (QR = 18.28–24.08 µg/l) and 200.90 ng/l (IQR = 178.70–215.80 ng/l), respectively. Mean Hb was 14.13 ± 1.78 g/dl. Only 4.55% of the study population had BLL >40 µg/dl [Figure 1].

No statistical significant correlation was observed between number of years of exposure at work and lead levels or EPP levels [Figure 2]. The median BLL was almost the same in those with ≤29 years of work exposure but started to increase in those with more than 30 years of exposure. Those with ≥40 years of exposure had the highest mean BLL [Figure 3]. A significant difference in median BLL was observed between those with <30 years of exposure and those with ≥30 years of exposure (P = 0.046) [Table 2]. Years of exposure at work were not significantly associated with median EPP levels [Figure 4].

BLL had a moderate negative correlation with RBC count (r = −0.322 P = 0.008) and a weak positive correlation with mean cell volume (MCV) (r = 0.277 P = 0.025). A significant correlation with other red cell indices was not observed. The red cell indices were also not significantly correlated with levels of EPP [Table 3], BLL and EP did not show a significant linear correlation (r=0.212, P=0.079). There was a statistically significant difference in means values of MCV, MCHC, and red cell distribution width (RDW) across different groups of BLL. *Post hoc* analysis showed that the difference in mean of these indices was between those with mean BLL <20 µg/dl and those with mean BLL >40 µg/l for MCV (P = 0.036) and between mean BLLs <20 µg/dl and those with mean BLL between 20 and 40 µg/dl for MCHC (P = 0.044) [Table 4].

White blood count and platelet count did not show statistically significant association with BLL [Table 5]. About 25.52% had anemia [Figure 5]. The proportion of participants with mild anemia was highest among those with mean BLL >40 µg/dl [Figure 6]. About 68.2% of study participants had MCV within normal range [Table 6]. The proportion of participants with MCV <80 fl (microcytes) was highest among those with BLL between 20 and 40 µg/dl [Table 6]. Moderate anemia was only observed among participants with BLL of between 20

Table 1: Characteristics of the study group

Parameter	n	Mean±SD	Median (IQR)
Age (years)	66	46.15±11.73	
Number of years at work	66	23.33±11.03	
Hour at work per day*	66		8.00 (7-10)
Blood lead level (µg/dl)*	66		20.75 (18.28-24.08)
EPP (ng/l)*	65		200.90 (178.70-215.80)
Hb (g/dl)	66	14.13±1.78	
WBCs (×10^9/L)*	66		5.17 (4.30-6.73)
Platelet (×10^9/L)	66	171.38±57.07	

*Data not normally distributed. SD: Standard deviation, IQR: Interquartile range, EPP: Erythrocyte protoporphyrin, Hb: Hemoglobin, WBCs: White blood cells

Table 2: Association between median blood levels and number of years of exposure at work

Number of years of exposure at work (years)	n	Mean rank (µg/dl)	Sum of ranks
<30	41	29.82	1222.50
≥30	25	39.54	988.50
Total	66		

Mann–Whitney U-test=361.500, P=0.046

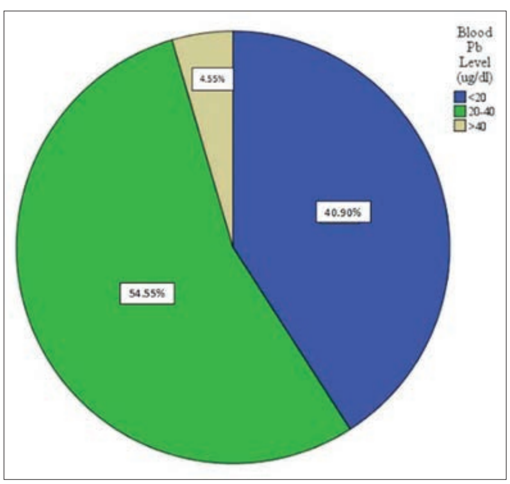

Figure 1: Blood lead levels among study population

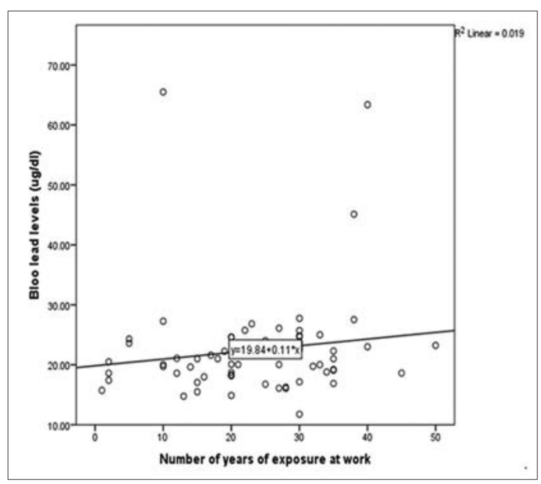

Figure 2: Correlation of number of years of exposure with blood lead levels

Table 3: Correlation between blood lead levels and erythrocyte protoporphyrin levels and red cell indices

Red cell indices	Mean±SD	Median (IQR)	Pearson correlation of BLL and EPP levels			
			BLL (μg/dl)		EPP levels (ng/ml)	
			r	*P*	*r*	*P*
PCV (%)		41.65 (40.15-44.55)	−0.156	0.212	−0.124	0.326
Hb (g/dl)	14.13±1.77		−0.155	0.0212	−0.038	0.762
RBC count (10^9/μl)	4.94±0.65		−0.322	0.008	−0.041	0.797
MCV (fl)	86.39±7.90		0.277	0.025	−0.113	0.371
MCH (pg)		28.50 (25.60-30.73)	0.219	0.077	0.026	0.835
MCHC (g/dl)	33.235±2.49		−0.045	0.718	−0.003	0.979
RDW (%)		13.55 (12.28-15.33)	0.009	0.940	0.033	0.748

BLL: Blood lead level, EPP: Erythrocyte protoporphyrin, SD: Standard deviation, IQR: Interquartile range, PCV: Packed cell volume, Hb: Hemoglobin, RBC: Red blood cell, MCV: Mean cell volume, MCHC: Mean cell hemoglobin concentration, MCH: Mean cell hemoglobin, RDW: Red cell distribution width

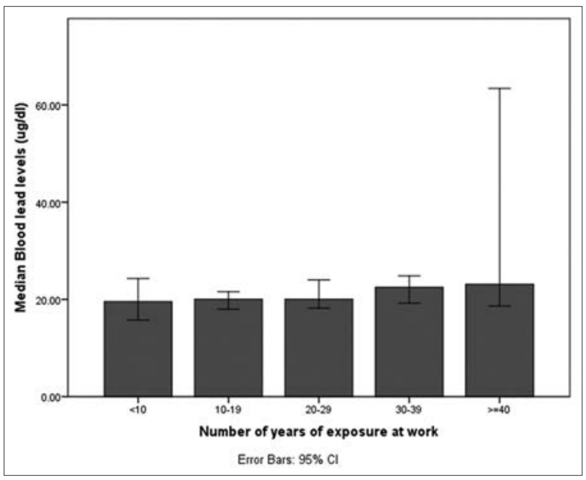

Figure 3: Number of years of exposure and median blood lead level

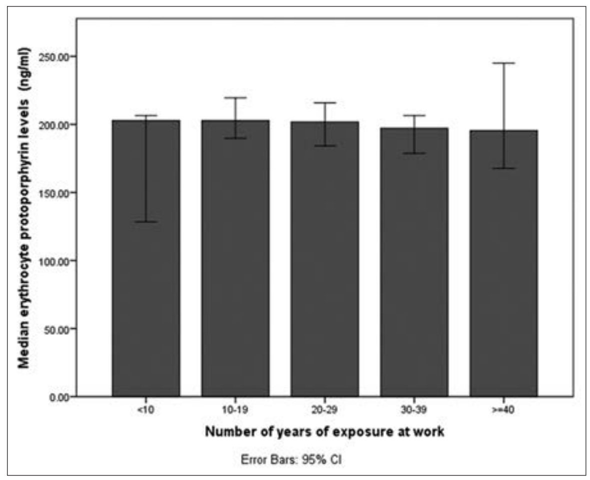

Figure 4: Number of years of exposure and median erythrocyte protoporphyrin levels

and 40 μg/dl. Platelet counts were normal in all strata of BLL, though an increasing tendency was observed with increasing BLL [Table 3]. This, however, was not statistically significant. Basophilic stippling was not observed in any of the participants.

All participants said they wear overalls and wash hands regularly before meals. However, only 13.6% use either gloves or facemasks [Table 7]. Fifty-three percent of participants were aware of the hazards related to their jobs and these participants had lesser BLL [Table 8]. Those who were aware of the hazards related with their jobs were 2.2 times more likely to use PPE than those with no awareness of occupational-related hazards, (odds ratio = 2.192, confidence interval = 1.651–2.911, $P = 0.002$).

Discussion

The onset of clinical lead intoxication is usually insidious and is associated with moderately elevated BLL over 20 ug/dl.[7] Therefore, determining and controlling lead exposure among these workers is very important. This study sought to investigate lead exposure among BCW and relate the level of exposure to their hematologic profile.

Measures of central tendency (median and mean) vary remarkably among workers in lead manufacturing plant/recycling and reconditioning factories as revealed in a review by Gottesfeld and Pokhrel.[6] The median BLL in this study was 20.75 μg/dl (IQR = 18.28–24.08 μg/dl) and is comparable to that reported in a study by Kalahasthi *et al*. and Sarathy Naidana *et al*. in India.[7,13] A lower mean BLL of 16.4 ± 8.5 μg/dl was reported among workers exposed to lead in Veles who were not necessarily battery factory workers.[14] In Nigeria, previous studies have reported higher mean BLL of 48.5 ± 9.08 μg/dl and 45.43 ± 6.93 μg/dl in Gwagwalada and Abeokuta, respectively. However, these studies were done among automechanics and not necessarily battery chargers.[15,16] Similarly, a study in Bangladesh also reported a high mean BLL (65.25 ± 26.66 μg/dl) among lead–acid battery workers.[17] Another study among BCW in Lagos gave mean BLL as high as 112.5 ± 14.94 μg/dl; however, in this study, even the controls had a high mean BLL of 45.60 ± 10.27 μg/dl.[18] Although the exact location in Lagos were this study done was not specified, the fact that both controls and BCW had high BLL suggests that there might be a high level of environmental pollution

Table 4: Means of red cell indices across strata of blood lead levels

Red cell indices	BLLs (μg/dl)			*P*
	<20	20-40	>40	
Hb (g/dl), mean±SD	14.41±1.80	13.94±1.76	13.83±1.85	0.569
PCV (%), median±IQR	42.33±4.62	42.59±4.54	38.00±4.24	0.323
RBC (×109/L), mean±SD	5.09±0.65	4.89±0.61	4.20±0.71	0.059
MCV (fl), mean±SD	84.36±6.82	87.12±8.25	96.00±5.20	0.036
MCH (pg), median±IQR	28.37±3.26	28.33±3.37	34.40±1.27	0.181
MCHC (g/l), mean±SD	34.02±2.29	32.55±2.53	34.43±1.18	0.044
RDW, median±IQR	5.09±0.65	4.89±0.60	4.21±0.997	0.002

BLLs: Blood lead levels, PCV: Packed cell volume, Hb: Hemoglobin, RBC: Red blood cell, MCV: Mean cell volume, MCHC: Mean cell hemoglobin concentration, MCH: Mean cell hemoglobin, RDW: Red cell distribution width, SD: Standard deviation, IQR: Interquartile range

Table 5: Other hematologic indices and blood lead levels

Blood Pb level (μg/dl)	Mean±SD	
	WBC (×10⁹/L)	Platelet (×10⁹/L)
<20	5.80±1.83	163.15±61.26
20-40	6.84±4.29	176.64±56.22
>40	5.47±1.05	182.33±12.86
F	0.827	0.442
P	0.481	0.620

WBC: White blood cell, SD: Standard deviation

Table 6: Mean cell volume among study participants

MCV (fl)	Frequency (%)
<80 (microcytic)	13 (19.7)
<80-96 (normocytic)	45 (68.2)
>96 (macrocytic)	8 (12.1)
Total	66 (100.0)

MCV: Mean cell volume

Table 7: The use of personal protective equipment among participants

Protective gadget/procedures	Yes (%)	No (%)	Total
Gloves	5 (7.6)	61 (92.4)	66
Face mask	8 (12.1)	58 (87.9)	66
Overalls	66 (100)	0 (0)	66
Handwashing before meals	66 (100)	0 (0)	66
Use of PPE (excluding overalls)	9 (13.6)	57 (86.4)	66
Awareness of hazard of job	35 (53)	31 (47)	66

PPE: Personal protective equipment

with lead in the study area. The lead level in Nigeria's super petrol is in range of 210–520 mg/l and adults living or working around highly trafficked areas such as bus terminals and fuel stations are unduly exposed to high concentration of larger and smaller particles sizes of lead on daily basis in air, water, soil, land even food.[19,20] The amount of exposure to lead in battery factories depend on the activities involved in each section

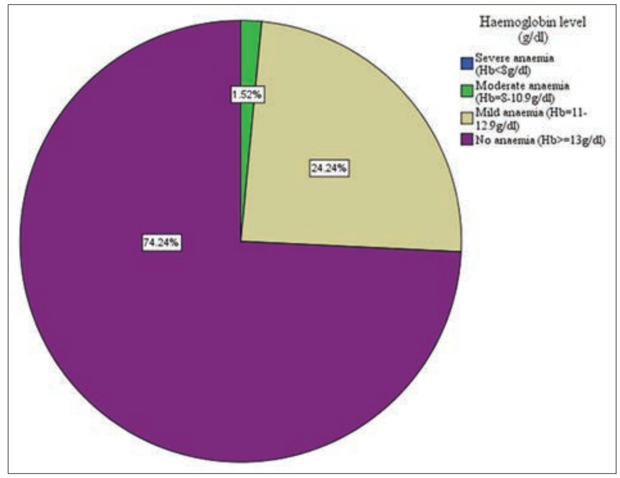

Figure 5: Frequency of the various degree of anemia among the study population

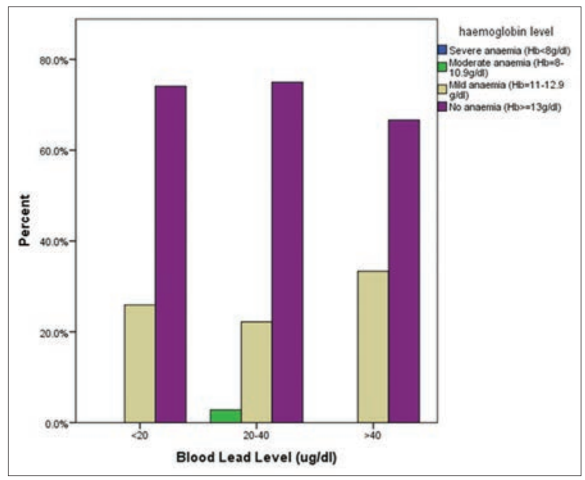

Figure 6: Degree of anemia at various level of blood lead levels

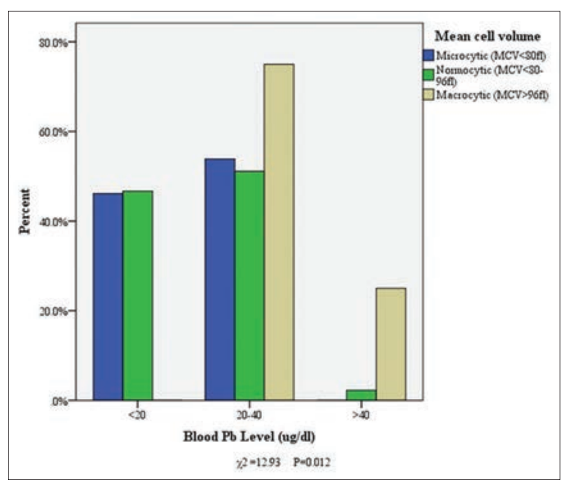

Figure 7: Mean cell volume and blood lead levels

Table 8: Association between mean blood lead levels and the use of personal protective equipment or awareness of occupational hazards

Use of protective gadgets/procedure	Mean BLL (μ/dl)		*t*	*P*
	Yes	No		
Gloves	20.46	22.60	−0.520	0.605
Face mask	20.65	22.68	−0.610	0.544
Awareness of hazard of job	20.29	24.86	−2.165	0.034

BLL: Blood lead level

as was demonstrated in a study comparing lead in air (PbA) with lead in blood among battery factory workers. This study related the values to PbA in 80 air samples collected at four operational areas in a battery industry to the BLL of workers in these various areas and hence demonstrated that workers in charging area had a lower mean blood level of 17.33 μg/dl compared to those in casting and pasting (32.19 μg/dl) and those in assembling (35.42 μg/dl). Lead air level followed a similar pattern.[21] This may explain why the mean BLL in our study was relatively lower.

In this study, it was observed that median BLL only started to rise significantly after about 30 years of exposure with those with ≥30 years of exposure having statistically significantly higher median BLL (39.54 μg/dl) than those with <30 years of exposure (29.84 μg/dl) $P = 0.046$ [Table 2]. Mean BLL was similarly reported by Stoleski *et al*. and Kianoush *et al*. to correlate to years of exposure.[14,22] Various factors such as age, sex, nutritional status, genetic background, route and duration of exposure, particle size, and solubility all affect BLL.[3,10]

Lead inhibits the activity of intramitochondrial enzyme ferrochelatase which leads to failure of the insertion of iron into the protoporphyrin ring and hence accumulation of EPP. It will be expected that with high BLL, EPP should also be high. However, in this study, EPP had no statistically significant linear relationship with BLL. Lilis *et al*. also reported the absence of significant correlation between BLL and ZP.[23] This may be due to the fact that the relationship between BLL and EPP is affected by a variety of other factors which include variability in lead exposure, the time lag between the increase in BLL and EPP and the precision of accuracy between the BLL and EPP.[24] Moreover, research has shown that significant increase in ZP is continually found only when BLL is higher than 30 μg/dl.[25,26]

The anemia of chronic lead poisoning results in depression of hem synthesis through its inhibitory effect on enzymes involved in hem synthesis. Reduction in hem synthesis usually lead to increase mitosis in red cell precursors and hence microcytosis. Reduced hem synthesis also leads to reduced hemoglobin synthesis and hence hypochromia. Hence, the anemia of chronic lead poisoning presents as a hypochromic and normo or microcytic anemia. The mean hemoglobin was 14.13 ± 1.78 g/dl. This is much higher than mean value reported by Kshirsagar *et al*. (11.89 ± 1.43 g/dl) and Sarathy Naidana *et al*. (12.5 g/dl), however, in these studies, mean BLL was 59.93 ± 9.57 μg/dl and 52.37 μg/dl, respectively.[7,8] Majority (74.24%) had normal. Proportion with mild anemia was highest among those with BLL >40 μg/dl and all those with moderate anemia had BLL between 20 and 40 μg/dl. Basophilic stippling was not seen in the peripheral blood smear of any of the participants. These may be related to the degree of exposure and the chronic nature of the exposure. Acute intoxication is more related with hemolytic anemia and may present with higher frequency of basophilic stippling. Environmental protection agency estimated the threshold BLL for a decrease in hemoglobin to be observed to be 50 μg/dl for occupationally exposed adults and approximately 40 μg/dl for children, though other studies have indicated a lower threshold of 25 μg/dl for children.[26] This may explain why <36% had anemia in this study.

BLL had a moderate negative correlation with RBC count ($r = -0.322$ $P = 0.008$) and a weak positive correlation with MCV ($r = 0.277$ $P = 0.025$). A study in Veles, however, reported a weak positive correlation with RBC count ($r = 0.258$, $P = 0.05$) and no correlation with MCV. The mean MCV, MCHC, and RDW were statistically different across the 3 strata of BLL. Lowest MCV was observed among participants with BLL between 20 and 40 ug/dl, while MCV was highest among those with BLL ≥40ug/dl though still within normal range. This is not expected as decrease in hem synthesis is associated with microcytosis; moreover, polychromasia was not observed in the blood film. Reticulocyte count was not done and this is a limitation in this study as increase in reticulocytes could explain the increase in MCV. Macrocytic anemia has however been reported among lead–acid battery workers.[17] Although Hb and PCV were not significantly correlated with BLL RBC count was and the mean RBC count fell as the BLL increased [Table 4]. Subclinical anemia in individual with high BLL has been documented.[27]

A study done in Tamil Nadu, India, also shows no correlation between the BLL and RBC indices. Only the reticulocyte count was correlated with BLL. Mean BLL among those with low exposure was 20.1 ± 5.1 ug/dl, while mean RBC count, Hb, and PCV were 5.3 ± 0.4, 14.8 ± 1.1, and 44.8 ± 3.0%, respectively. This values are similar to what was observed in this present study [Table 1].[13]

Personal hygiene behaviors have been assumed to be a modifier of lead exposure empirically. However, in this study, the use of PPE had no statistically significant effect on BLL. In a study on BLL of apprentices in lead-related industries in Bursa, Turkey, the persistent use of mask was the only PPE shown to be related to BLL. Those who used mask had significantly lower BLL compared with those who did not, emphasizing the fact that the source of most occupationally acquired blood lead among workers in the lead industry is through inhalation.[28] Sarathy Naidana *et al*. also found that BLL was not statistically different among unhygienic workers and hygienic workers.[7]

In this study, those who were aware of risk associated with their job had significantly lower BLL than those who were ignorant [Table 8]. More so, those who had awareness of the job-related risk also tended to use PPE.

Conclusion

The findings suggest that BCW involved in charging only had a moderate exposure which is not enough to lead to significant hematologic effect. Awareness of occupational risk increases the likelihood of using PPE and thus reducing occupational exposure to lead. Regular monitoring of BLL and hemogram among at-risk population coupled with continuous public education will reduce health hazard associated with occupational/environmental exposure to lead.

Recommendation

Improper use of PPE may account for the lack of relationship observed in our study; however, this was not assed. It is recommended that a study on the knowledge, attitude, and practice of use PPE be evaluated in this study population. Furthermore, continuous education on occupational hazard related to work and the benefits of appropriate use of PPE to persons at risk is recommended.

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Conflicts of interest

There are no conflicts of interest.

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