Effectiveness of interventions on biological monitoring among workers exposed to Pb from lead-acid storage battery plant

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Abstract

Background: Studies related to the effectiveness of combined interventions such as engineering and administrative controls, use of a respirator, and conducting awareness program about lead exposure on biological monitoring among lead battery workers were not reported.

Objective: This study has assessed the effectiveness of interventions on biological monitoring among lead battery manufacturing workers.

Materials and Methods: The intervention methods were use of a respirator, awareness program about lead exposure, engineering and administrative controls. Blood lead levels (BLLs) among workers were estimated using an atomic absorption spectrophotometer. Hematological parameters in workers were determined using Fx-19E automated hematology analyzer. Reticulocyte count in workers was done using supravital staining method.

Results: The mean systolic and diastolic blood pressure, the proportion of alcohol consumption, and smoking habits were noted to be significantly decreased among workers after the intervention. The BLLs were reduced significantly among workers engaged in assembly, casting, engineering services, formation, acid filling, and in executives after the intervention. The red cell indices such as erythrocytes and hematocrit were significantly increased and mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, and reticulocyte count were significantly decreased after the intervention.

Conclusions: Austere implementation of control measures in lead-acid storage battery plant showed beneficial health effects among lead exposed workers.

KEY WORDS: Blood lead levels, interventions, biological monitoring, lead battery workers

Introduction

Manufacturing of lead-acid storage batteries involves several processes, such as preparation of lead oxide, grid casting, pasting, plate cutting, formation, charging, and assembly. The chemicals used in these processes are of hazardous nature, and these include lead oxide (PbO_2), spongy lead (Pb), and sulfuric acid (H_2SO_4). Lead enters the body of workers by inhalation and ingestion. After entry into the body, the lead will accumulate in erythrocytes, soft tissue (brain, kidney, and bone marrow), and mineralized tissue (bone, teeth).[1] Chronic exposure to Pb during the lead battery manufacturing process leads to a variety of health problems. Previous studies have reported association between blood lead levels (BLLs) with neurobehavioral impairments,[2] genotoxic effects,[3] impaired coagulation,[4] health illness,[5] hypertension,[6] decreased δ-aminolevulinic acid dehydratase & elevated δ-aminolevulinic acid,[7] ocular changes,[8] respiratory, gastrointestinal & musculoskeletal morbidities,[9] epigenetic changes,[10] decreased bone mineral density,[11] oxidative stress,[12] dental problems,[13] altered

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gene polymorphisms,[14–16] increased risk of cardiovascular disease,[17] anemia & abdominal pain[18]; and decreased enzymatic antioxidants[19] among lead battery manufacturing workers.

Sato and Yano[20] reported hand contamination was positively associated with BLLs. The variety of household interventions such as home wet cleaning activity; dust control; parental knowledge about lead exposure; and reduction of lead in soil, petrol, and paints will reduce lead poisoning in children.[21–23] Dyosi[24] studied the effect of interventions of engineering and administrative controls and use of personal protective equipment for lead exposure from lead smelting process and suggested that engineering controls were rated the best control measure. Lee et al.[25] assessed the use of respirators on biological monitoring among lead battery workers. The result of the study found a significant decrease of BLLs, δ-aminolevulinic acid, and lead-related symptoms. Studies related to effectiveness of combined interventions such as engineering and administrative controls, use of a respirator, and conducting awareness program about lead exposure on the status of biological monitoring among workers from lead-acid storage battery manufacturing plant were not reported. The present study was carried to assess the effectiveness of interventions on biological monitoring among workers involved in lead-acid storage battery plant.

Materials and Methods

The study design was quasi-experimental time series, the data were collected in two phases with pre- and postintervention. The preintervention phase assessment was conducted during July 2013 and postintervention assessment was conducted during July 2014. Informed consent was taken from each worker before participation in the study. The study was approved by Institutional Ethical Committee. In pre- and postintervention phases, the demographic details, blood pressure, BLLs, and hematological parameters were assessed in 397 male lead workers involved in lead-acid storage battery plant.

Intervention Methods

1. Engineering controls: (1) Plate cutting area was relocated and rerouting of exhaust ducts carried out to improve the assembly work environment. (2) The placing of roof-mounted humidifiers to provide cold air for worker comfort and dust suppression. (3) Installation of the water bath at plate cutting area to trap dust emissions.

2. Administrative controls: (1) Motorized road cleaning machine was introduced to minimize the dust exposure. (2) De-leaded hand wash solution was used to avoid hand contamination in workers.

3. Personal protective equipment: Workers used half face mask (V 800) for respiratory protection during their work.

4. An awareness program about lead exposure was conducted.

Demographic Details

The demographic details such as age, sex, experience, body mass index (BMI), occupational health history, smoking, and alcohol consumption habits among workers were collected using a predesigned validated questionnaire. BMI was calculated by noting the height and weight of each worker and expressed as kg/m^2.

Blood Pressure

A health physician measured the blood pressure of on right arm, while the worker was in a sitting position. A standard mercury sphygmomanometer worker was used for blood pressure monitoring.

Blood Lead Level

Three milliliters of venous whole blood was collected in heparinized vacuette from the workers and stored at –20°C until analysis. Two milliliters of blood was digested by using an ETHOS-D, milestone microwave system (Italy) with 2 mL of nitric acid (HNO_3) and 0.2 mL of hydrogen peroxide (H_2O_2) by maintaining power, temperature, duration of time. The digested samples were made up to 5 mL using triple distilled water and centrifuged. The concentration of lead in blood was measured by using an atomic absorption spectrophotometer (GBC-Avanta P. Australia). A standard solution of 20 µg/dL was prepared from the lead standard solution of Merck (1.19776.0500) and added to the lowest concentration of the sample and the analysis found 100% of recovery with % RSD at <0.5 for three replicates. BLLs were expressed as µg/dL.

Hematological Parameters

A volume of 2 mL of venous whole blood was collected in a Lavender Top Vacutainer Tube, which contains tripotassium–EDTA. The levels of red blood cell (RBC) count, hematocrit mean corpuscular volume, mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) were determined by a Fx-19E automated hematology analyzer.

Reticulocyte Count

Non-nucleated immature RBCs contain nuclear remnants of RNA known as a reticulocyte. The reticulocyte counts in peripheral blood samples were done using the supra-vital staining method. The reticulocyte counts in the workers were expressed as percentage.

Statistical Analysis

Software package SPSS, version 16.0 for windows was used for the analysis of data. The data of age, experience, BMI, blood pressure (BP) (systolic BP [SBP] and diastolic BP [DBP]), BLLs, and hematological parameters were presented as mean ± standard deviation. The effectiveness of interventions on BLLs was assessed using McNemar test. Smoking and alcohol consumption habits among workers were reported in percentage and compared using the chi square test. The probability value of less than 0.05 considered as significant.

Results

The demographic details among workers in pre- and postintervention groups were presented in Table 1. The mean SBP DBP the proportion of smoking and alcohol consumption habits were significantly decreased in the postintervention group as compared to the preintervention group. No significant difference was observed with respect to age, experience and BMI.

BLLs among workers, according to their job categories of pre- and postintervention groups, were reported in Table 2. The BLLs were significantly decreased in workers from assembly, casting, engineering services, formation, acid filling in executives. No significant differences were observed in pasting, ball mill, charging, and plate cutting area.

BLLs between pre- and postintervention groups according to Biological Exposure Index of American Conference of Governmental Industrial Hygienist was presented in Figure 1. The effectiveness of the intervention on BLLs was assessed using the McNemar test, which showed significantly ($P < 0.001$) decreased BLLs.

Hematological parameters among workers, according to pre- and postintervention groups were reported in Table 3. The levels of erythrocyte count and hematocrit were significantly increased and MCH, MCHC, and reticulocyte count were significantly decreased in the postintervention group as compared to the preintervention group.

Table 1: Demographic detail of workers in pre- and postintervention groups

Variables	Preintervention (n = 397)	Postintervention (n = 397)
Age (years)	36.0 ± 4.8	37.0 ± 4.9
Experience (years)	12.6 ± 3.9	13.8 ± 4.1
BMI (kg/m^2)	25.6 ± 2.9	25.6 ± 2.8
SBP (mm/Hg)	128 ± 14	123 ± 13**
DBP (mm/Hg)	78 ± 11	73 ± 10**
Smoking habits (%)	93 (23)	77 (19)**
Alcohol consumption	213 (54)	203 (51)*

**$P < 0.001$ and *$P < 0.05$.

Discussion

The present study assessed the effectiveness of interventions on biological monitoring among workers exposed to lead from lead-acid-storage battery plant. The intervention methods adopted were engineering administrative controls, use of respirators, and awareness program conducted about lead exposure. During the study, SBP, DBP, proportion of alcohol consumption, and smoking habits were significantly reduced in the postintervention group as compared to the preintervention group. Dickenson et al.[26] reported that lifestyle intervention such as weight reduction and restriction of alcohol, smoking, and salt intake significantly reduced the BP as compared to the nonintervention group. The altered lifestyle factors might have influenced the reduction of SBP and DBP in the postintervention group. A recent study reported that BLLs were associated with elevated BP.[27] The reduction in BLLs might have influenced the reduction BP among workers. Karita et al.[28] reported that the nonsmokers have decreased BLLs as compared to smokers. In the present study, the decreased proportion of smoking habits among postintervention might contribute to the reduction of BLLs. This finding was similar to that of Chuang et al.[29] as restriction of smoking and eating at work places influences reduction in BLLs.

Ochieng et al.[30] studied the effectiveness of health education and hygiene practices on BLLs among lead battery workers in Nairobi. The authors concluded that use of Personal Protective Equipment (PPE) and health education significantly associated with decreased BLLs. Lormphongs

Table 2: Blood lead levels (μg/dL) among workers according to job categories in pre- and postintervention groups

Job categories	Preintervention	Postintervention	Difference in means	Decrease (%)
Assembly (n = 193)	34.6 ± 12.8	28.0 ± 11.4**	6.6	19.0
Casting (n = 40)	29.3 ± 9.8	23.8 ± 10.7*	5.5	18.7
Pasting (n = 37)	33.5 ± 12.1	33.2 ± 13.1	0.3	0.9
Ball mill (n = 9)	34.3 ± 7.7	27.2 ± 11.0	7.1	20.7
Charging (n = 18)	22.3 ± 7.0	17.2 ± 9.3	5.1	22.8
Plate cutting (n = 6)	37.0 ± 14.6	31.3 ± 7.4	5.7	15.4
Engineer services (n = 48)	31.2 ± 12.0	22.1 ± 9.4**	9.1	29.2
Formation (n = 4)	26.5 ± 6.5	13.5 ± 2.9*	13.0	49.5
Acid filling (n = 10)	29.8 ± 9.5	21.6 ± 9.7*	8.2	29.5
Executives (n = 32)	35.6 ± 14.0	27.1 ± 12.4*	8.5	23.8
Total	32.8 ± 12.3	26.5 ± 11.7**	6.3	19.2

**$P < 0.001$ and *$P < 0.05$.

Table 3: Hematological parameters in workers according to pre- and postintervention groups

Variables	Preintervention	Postintervention
RBC (million/µL)	4.23 ± 0.38	4.32 ± 0.46*
Hematocrit (%)	36.9 ± 3.0	37.7 ± 4.2*
MCV (fl)	87.7 ± 7.1	87.6 ± 7.8
MCH (pg)	34.5 ± 3.3	32.6 ± 4.6*
MCHC (%)	39.3 ± 2.3	37.2 ± 3.8*
Reticulocyte count (%)	0.84 ± 0.3	0.66 ± 0.2*

*$P < 0.05$.

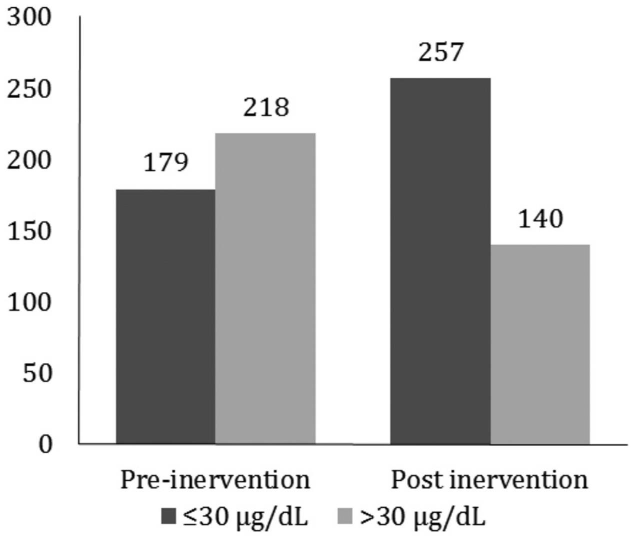

Figure 1: Blood leads levels among pre- and postintervention workers according to Biological Exposure Index—ACGIH criteria.

et al.[31] also reported that the occupational health education causes decreased BLLs among lead-acid-storage battery workers. Esswein et al.[32] reported that hand contamination was positively associated with BLLS. Dyosi[24] studied the effect of engineering and administrative controls and use of personal protective equipment for lead exposure from lead smelting process and suggested engineering controls were rated the best control measure. Lee et al.[25] assessed the effectiveness of the respirator on biological monitoring on the health management of lead battery workers. That study found significantly decreased BLLs, δ-aminolevulinic acid, and lead-related symptoms. In the present study, engineering administrative controls and use of respirators were implemented and also awareness program was conducted to minimize lead exposure. BLLs were significantly reduced in assembly, casting, engineering services, formation, acid filling and in executive job categories of postintervention group. The present study also assessed the hematological parameters in pre- and postintervention groups. The mean levels of erythrocytes and hematocrit significantly increased and MCH, MCHC, and reticulocyte counts were significantly decreased in the postintervention group as compared to the preintervention group. Saichanma et al.[33] also noticed higher level of the RBC count with low levels of MCH and MCHC. The findings of this study were similar to previous studies.

Conclusion

The variables of BLLs, hematological parameters, and lifestyle factors were significantly improved in the postintervention as compared to the preintervention group. These study findings indicate the beneficiary effects in terms of biological monitoring with the austere implementation of control measure in the lead-acid battery plant.

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