Blood lead level, cognitive and psychomotor activity in lead exposed battery workers

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Abstract. Lead, a systemic toxicant affecting virtually every organ system, primarily affects the central nervous system. The aim of the present study was to determine and compare blood lead level, cognitive and psychomotor ability level in the non-exposed subjects and lead-exposed battery workers and to find out the relationship between these parameters in the lead-exposed battery workers. This cross-sectional study included 28 non-exposed subjects and 28 lead-exposed battery workers from small-scale battery workplaces in Insein and North Okkalapa Townships. The blood lead level (BLL) was determined by graphite furnace atomic absorption spectrometry. The cognitive ability was assessed by using three subtests from the General Memory Scale (GMS). The psychomotor ability tests composed of digit symbol, Bourdon-Wiersma vigilance test and the Santa Ana dexterity test. The mean BLL of the lead-exposed battery workers (4.25 ± 3.87 µg/dL) was significantly higher (P<0.01) than that of the non-exposed subjects (2.14 ± 1.02 µg/dL). After matching age, sex, socio-economic status and educational level, it was found that mean scores of cognitive and psychomotor ability tests (digit span, paired associate learning and Santa Ana dexterity) of the lead-exposed battery workers were significantly lower than those of the non-exposed subjects. It was concluded that even low lead exposure could reduce the cognitive and psychomotor abilities, especially in attention, concentration, short-term memory and perceptual motor ability domains in adult male workers.

1. Introduction
Lead (Pb, relative atomic mass 207.2) is a non-physiological metal that has been used by humans for many technological purposes. Routes of exposure for this heavy metal include ingestion, inhalation and dermal contact [1]. Among the organ systems affected by lead, the central nervous system (CNS) has received much attention. The ability of lead to pass through the blood-brain barrier is due in large part to its ability to substitute for calcium ions [2]. Ataxia and memory loss are the common manifestations of lead intoxication in brain and at high exposure levels it will lead to coma and death [3]. Low to moderate exposure has been consistently associated with symptoms of malaise, fatigue, irritability, lethargy, headache, and decreased libido [4]. Balbus-Kornfeld et al. (1995) reported that such exposure decreases neuro-behavioural test scores in the cognitive or motor domains of psychomotor speed, manual dexterity, memory, and learning ability [5].

2. Materials and Methods
A cross-sectional study included lead-exposed battery workers (n=28) and non-exposed subjects (n=28), aged 20-45 years. For lead-exposed workers, those working in small-scale battery workplaces in Insein and North Okkalapa Townships, Yangon with a history of working as a battery worker for at least one
year were recruited. For non-exposed group, age, sex, socio-economic status and educational level matched apparently healthy male subjects were recruited.

They were explained about the experiments and then written informed consents were obtained. History taking and physical examination including anthropometric assessment were done. They were instructed to take 10-hour overnight fasting, starting from 10:00 pm to 8:00 am. Blood samples were taken at 8:00 am on the next morning at the workplace for battery workers. About 4 ml of blood was withdrawn from antecubital vein under aseptic condition and was delivered gently into heparinised tube for blood lead determination. Blood lead level was measured by Graphite Furnace Atomic Absorption Spectrophotometric method.

After 5-minute sitting rest, they were explained about the procedure for assessment of cognitive and psychomotor ability. The cognitive function of the subjects was assessed by using three subtests from the General Memory Scale (GMS) although it contains seven subtests. It is originated from the Weschler Memory Scale (1956) and adopted to Myanmar version by Ohn-Kyaw and Ohn-Hlaing (1980) [6]. The included subtests in GMS are Digit Span for ability to remember the sequence of the numbers (backward and forward), Paired Associated Learning for new concepts formation and Visual Memory for recall and recognition. The psychomotor ability measurements comprised tests covering the perceptual motor ability and attention concentration functioning, which are generally regarded as sensitive indicators of impairment of brain function. Thus, the digit symbol (DSy) and Bourdon-Wiersma vigilance tests (B-W) were selected to provide speed and accuracy of visual motor performance, whereas the Santa Ana dexterity test (SA) to provide a measure of manual dexterity and eye hand coordination.

Total time of these two tests was taken about 45 minutes for each subject. The score sheets of GMS and psychomotor ability tests were done by the researcher according to the instructions given. Data was presented as mean ± SD. Data analysis was done by using the Statistical Package for Social Sciences (SPSS) software version 16. The difference between the means of battery workers and control group was assessed by Student’s t test. Pearson’s correlation coefficients were computed to explore strength and significance of the relationships among variables. The statistical significance level was set at p = 0.05.

3. Results
Baseline characteristics of the non-exposed subjects and lead-exposed workers are shown in table 1. Mean blood lead level (BLL) of the non-exposed subjects (n = 28) was 2.14 ± 1.02 μg/dL and that of the lead-exposed battery workers (n = 28) was 4.25 ± 3.87 μg/dL.
Table 1. Baseline characteristics of the subjects.

| Parameter                        | Non-exposed subjects (n = 28) | Lead-exposed battery workers (n = 28) | P value |
|----------------------------------|-------------------------------|--------------------------------------|---------|
| Completed age (years)            | 27.8 ± 9.23                  | 27.8 ± 9.19                          | NS      |
| Weight (kg)                      | 53.05 ± 9.32                 | 56.74 ± 10.2                         | NS      |
| Height (m)                       | 1.63 ± 0.07                  | 1.63 ± 0.07                          | NS      |
| Body mass index (kg/m²)          | 20.03 ± 2.77                 | 21.29 ± 3.08                         | NS      |
| Resting heart rate (beats/minute)| 78.8 ± 3.82                  | 74.9 ± 6.00                          | 0.006   |
| Resting systolic blood pressure (mmHg) | 118.5 ± 5.59         | 117.5 ± 6.94                         | NS      |
| Resting diastolic blood pressure (mmHg) | 74 ± 5.47                | 72.9 ± 5.06                          | NS      |
| Duration of lead exposure (years)| _                            | 5.4 ± 7.02                           | _       |

1. Data are presented as mean ± SD
2. NS = no significant difference

Figure 1. Comparison of blood lead level between the non-exposed subjects and lead-exposed battery workers.
Solid line indicates mean of different groups. ** indicates significant difference (p < 0.01)
Table 2. Comparison of cognitive and psychomotor ability test scores between the non-exposed subjects and lead-exposed battery workers.

| Parameters                        | Non-exposed subjects (n=28) | Lead-exposed battery workers (n=28) | P value |
|-----------------------------------|-----------------------------|------------------------------------|---------|
| **Cognitive ability tests**       |                             |                                    |         |
| - Digit span                      | 12.04 ± 1.90                | 10.64 ± 2.23                       | 0.015   |
| - Visual memory                   | 5.64 ± 0.38                 | 5.48 ± 0.48                        | 0.172   |
| - Pair associated learning        | 21.98 ± 6.62                | 15.84 ± 6.79                       | 0.001   |
| Total score                       | 39.66 ± 7.54                | 31.96 ± 7.70                       | 0.000   |
| **Psychomotor ability tests**     |                             |                                    |         |
| - Digit symbol                    | 49.21 ± 18.85               | 43.46 ± 14.71                      | 0.209   |
| - BW speed test (min)             | 7.31 ± 2.29                 | 6.55 ± 1.73                        | 0.167   |
| - BW error test                   | 10.29 ± 8.02                | 14 ± 9.73                          | 0.125   |
| - SAD Rt (sec)                    | 50.54 ± 7.49                | 56.57 ± 8.13                       | 0.006   |
| - SAD Lt (sec)                    | 53.07 ± 6.83                | 60.36 ± 10.79                      | 0.004   |
| - SAD both (sec)                  | 41.92 ± 5.48                | 44.36 ± 9.82                       | 0.26    |

Table 3. Correlation between blood lead level and cognitive and psychomotor ability test scores of the lead-exposed battery workers.

| Parameters                        | Pearson's r | P value |
|-----------------------------------|-------------|---------|
| BLL vsTotal cognitive scores      | 0.145       | 0.461   |
| - Digit span                      | -0.18       | 0.36    |
| - Visual memory                   | 0.328       | 0.088   |
| - Pair associated learning        | 0.2         | 0.307   |
| BLL vs Psychomotor ability scores |             |         |
| - Digit symbol                    | 0.042       | 0.831   |
| - BW speed test (min)             | -0.314      | 0.104   |
| - BW error test                   | 0.007       | 0.973   |
| - SAD Rt (sec)                    | -0.016      | 0.935   |
| - SAD Lt (sec)                    | 0           | 1       |
| - SAD both (sec)                  | 0.055       | 0.78    |

Regarding cognitive ability scores, mean total score of cognitive ability tests in lead-exposed battery workers was significantly lower (p = 0.01) than that of non-exposed subjects. It was also found that 2 out of 3 test scores (i.e. digit span and paired associate learning test) were significantly lower in the lead-exposed battery workers than non-exposed subjects. It was noted that there was no significant difference in visual memory score between non-exposed and lead-exposed subjects. Concerning psychomotor ability tests, no significant difference in digit symbol, Bourdon-Wiersma vigilance speed and error test was seen in the present study. A significant difference was seen in the mean score of SAD (right hand and left hand) of non-exposed subjects and lead-exposed battery workers. Correlation between blood lead level and cognitive and psychomotor ability test scores was not found in the lead-exposed battery workers.
4. Discussion

In the present study, mean BLL of the lead-exposed battery workers (n=28) was 4.25±3.87 µg/dL and that of the non-exposed subjects (n=28) was 2.14±1.02 µg/dL. The recommended level for safety was <5 µg/dL according to CDC (2016) [7]. Among 28 lead-exposed workers, 5 subjects have BLL >5 µg/dL, but <10µg/dL. However, it was found that participants in both groups of the present study had a low lead exposure, and that BLL of the non-exposed subjects was significantly lower than that of the lead-exposed battery workers.

According to previous Myanmar study, mean BLL of the non-exposed subjects and lead-exposed battery workers were 6.98±2.18 µg/dL and 48.45±19.96 µg/dL, respectively [8]. Another Myanmar study also reported that mean BLL of control group was 19.83±4.7 µg/dL, and that of the lead-exposed battery workers was 80.21±28.63 µg/dL [9]. It was noted that BLL of the participants in the present study was markedly lower than that of the participants from the previous Myanmar studies. These previous studies were conducted in battery factory workers. The discrepancy might probably be due to reduced direct handling of lead and/or low lead exposure. Nowadays, imported sealed-typed batteries with reasonable prices become more available and are widely used in Myanmar. The participants of the present study worked in small-scale battery workplace and their job is just to repair and recycle the batteries, thus direct handling of lead might have been reduced. Moreover, it could also be due to taking preventive measures during lead handling, as these battery workers are aware of the hazards of lead toxicity.

Blood samples of the non-exposed subjects in the present study also contain lead. Actually, the non-exposed subjects were selected from those who do not work in the battery industries or small-scale battery shops. Thus, the presence of lead in the blood samples of the non-exposed subjects might be due to exposure of lead from the sources other than the battery work places. Malekirad et al. (2013) stated that lead exposure is inevitable because of its accumulation in the environment and commonly used in everyday life [10]. Non-exposed subjects might have been exposed to lead through the ingestion of lead-contaminated food or drinking water containing lead leaching from older corroding pipes and fixtures, inhalation in industrial settings, and dermal contact.

Regarding cognitive ability scores, mean score of digit span of the non-exposed subjects was 12±1.9, while that of the lead-exposed workers was 10.6±2.2. Yadanar-Tint-Lwin (2015) reported that mean score of digit span test of medical students was 13.28 [11]. The scores of the non-exposed subjects of the present study were not markedly different from that of medical students in previous Myanmar study which also used GMS. So, the digit span scores of the non-exposed subjects can be assumed as normal and the scores of lead-exposed battery workers were found to be significantly lower than that of the non-exposed subjects.

The mean of visual memory score of the non-exposed subjects of the present study was 5.6±0.4, and that of battery workers was 5.5±0.5. These values were consistent with the finding of Yadanar-Tint-Lwin (2015) in which the mean score of medical students (n = 62) was 5.6 [11]. It was also noted that there was no significant difference in visual memory score between the non-exposed and exposed workers. However, Kumar et al. (2002) reported a significant difference in both digit span and visual memory scores between control group and battery workers [12]. The mean score of paired associate learning test was significantly higher in the non-exposed subjects (22±6.62) than the lead-exposed battery workers (15.8±6.8). Yadanar-Tint-Lwin (2015) found that the mean score of paired associate learning of medical students was 16.79 [11]. The result of the paired associate learning test was not consistent with that of Yadanar-Tint-Lwin (2015). To sum up about the cognitive ability test, it was found that 2 out of 3 test score (digit span and paired associate learning) were significantly lower in the lead-exposed battery workers than non-exposed subjects.

Concerning psychomotor ability test scores, there were no previous Myanmar studies to compare the results. The mean score of digit symbol of the non-exposed subjects was 49.2±18.8 whereas that of the lead-exposed battery workers was 43.5±14.7 (p = 0.2). Sahani and Ismail (1995) demonstrated that the mean score of digit symbol of BLL <40 µg/dL group was 49.6 and that of BLL >40 µg/dL group was 37.4 (p = 0.02) [13]. There was no significant difference in digit symbol, Bourdon-Wiersma vigilance.
speed and error test in the present study. A significant difference was seen in the mean score of SAD (right hand test and left hand test) of non-exposed subjects and lead-exposed battery workers but there was no significant difference in SAD both hands test. Contrary to the present findings, a significant difference in these test scores was found in Jeyaratnam et al. (1986) [14]. The BLL of the participants in Jeyaratnam et al. (1986) was also >40 μg/dL. Taken the findings of the present study and the previous studies together, no significant reduction in psychomotor ability might be due to low lead exposure in the exposed battery workers participated in the present study.

In conclusion, the present findings suggested that attention concentration domain, short-term memory and perceptual motor ability domain were mainly affected in the lead-exposed battery workers even in low lead exposure. The presence of lead in the non-exposed subjects also indicated that they are also exposed to lead, probably from environmental sources rather than battery work. Therefore, it is important for public health point of view. Previously, the importance of lead exposure has not been considered to be one of the factors of impaired cognition. Health education should be given to raise public awareness of health hazards and to take preventive measures in dealing with lead contaminated substances and disposal of lead contaminated wastes.

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