Blood lead and erythrocyte protoporphyrin levels in association with smoking and personal hygienic behaviour among lead exposed workers

K Karita, M Nakao, K Ohwaki, Y Yamanouchi, M Nishikitani, K Nomura, M Sato, E Yano

SUBJECTS AND METHODS

The study included 105 lead exposed male workers who had been working in eight departments of distinct operational areas at a battery recycling plant in Japan during 2000–03. The mean age was 47 years (SD 12, range 22–68). The mandatory health check-up was conducted under the Industrial Safety and Health Law in Japan, and levels of BPb and urinary δ-aminolevulinic acid of the workers were regularly monitored by routine medical screening. From 2000, health education for the workers has been promoted by industrial physicians and hygienists in the plant, and the mean level of BPb, which had been at a constant level before 1999, was decreased from 46 to 36 μg/dl between 2000 and 2003. On average, the highest levels of BPb were observed for workers in a smelting area, followed by those in an electrolytic area. Lead in ambient air suspended in the whole workplaces ranged from 0.02 to 0.55 mg/m³ with an average of 0.17 in 2003 (n = 60; data for 2000 and 2002 were not available). All workers gave fully informed consent. Ethical approval for the study was given by the committee for labour and safety in the plant.

Blood was collected by venipuncture using sodium heparin as anticoagulant as part of the regular occupational surveillance for prevention of lead poisoning. BPb was analysed by graphite furnace atomic absorption spectrophotometry as described previously; the detection limit was 1.0 μg/dl blood. FEP was determined by a modified Piomelli method using fluorometry after acid extraction. Thus the effectiveness of hygienic behaviour in lead exposed workplaces could be evaluated using both FEP as a sensitive index and BPb as a biomarker of internal lead burden.

The aim of this study was to investigate the influence of smoking and personal hygienic behaviour on lead intake by monitoring BPb and FEP continuously, and to assess the contribution of the behavioural factors to the decrease of BPb and FEP in a cohort of Japanese lead exposed workers.

Aims: To investigate the effects of smoking and personal hygienic behaviour on blood lead (BPb) and free erythrocyte protoporphyrin levels (FEP) in lead exposed workers.

Methods: Subjects were 105 lead exposed male workers in a battery recycling plant during the years 2000–03. BPb and FEP were measured as part of the ongoing occupational surveillance. Each worker completed a questionnaire for assessment of smoking and four measures of personal hygienic behaviour (glove and mask use, hand and face washing before meals during working hours).

Results: Statistically significant decreases in mean BPb and FEP occurred during the three years. The proportion of BPb reduction in the non-smoking workers was significantly higher (mean 24.3%) than in the smoking workers (15.3%). When the workers were classified into three groups (ex-smokers, current smokers, and non-smokers) based on the four personal hygienic behavioural indicators, the greatest decreases of BPb and FEP were observed in the non-smoking workers of the excellent group.

Conclusions: The consistent use of protection devices and cleanliness at work appeared to contribute to the lowering of BPb and FEP. Cessation of smoking in the workplace was also of importance.
**Main message**

- The consistent use of protection devices and smoking cessation in the workplace appeared to contribute to the lowering of blood lead and erythrocyte protoporphyrin levels.

**RESULTS**

The number of the current smokers in 2003 was 62 (59% of study subjects); average number of cigarettes smoked per day was 21 (SD 6). The smoking pattern was homogeneous—all the smokers reported that they usually smoked in their working areas when they took a rest during on-duty hours. The number of the current smokers in 2003 was 62 (59% of study subjects); average number of cigarettes smoked per day was 21 (SD 6). The smoking pattern was homogeneous—all the smokers reported that they usually smoked in their working areas when they took a rest during on-duty hours. The number of current smokers (p = 0.0054 by one way ANOVA) and ex- or never smokers (p = 0.0062), and were significantly different between 2000 and 2003 by Scheffe’s test irrespective of smoking habits (p = 0.0006). Student’s t test or Scheffe’s test were used to compare the mean values between groups when the normal distribution was assumed by the Shapiro-Wilk test. The Wilcoxon test was used to analyse the differences between the two groups with skewed distributions. The differences in BPb and FEP changes among the behavioural groups were analysed by two way repeated measures analysis of variance (ANOVA), using the model of type II sum-of-squares with F ratios based on the residual mean square error. A level of p < 0.05 was regarded as statistically significant. All statistical analyses were performed by using the Statistical Package for the Biosciences (SPBS v9.5).12

**Table 1** Comparison between current smokers and ex- or never smokers in mean levels of BPb (µg/dl) and FEP (µg/dlRBC) in 2000 and 2003

<table>
<thead>
<tr>
<th>Year</th>
<th>Current smoker Mean (SE) [n = 62]</th>
<th>Ex- or never smoker Mean (SE) [n = 43]</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPb in 2000</td>
<td>47.6 (1.8)</td>
<td>43.0 (2.0)</td>
<td>0.0971</td>
</tr>
<tr>
<td>BPb in 2003</td>
<td>40.4 (2.0)</td>
<td>32.4 (1.9)</td>
<td>0.0057</td>
</tr>
<tr>
<td>% reduction</td>
<td>13.3 (2.6)</td>
<td>24.3 (2.7)</td>
<td>0.0238</td>
</tr>
<tr>
<td>FEP in 2000</td>
<td>268 (27)</td>
<td>196 (24)</td>
<td>0.0624</td>
</tr>
<tr>
<td>FEP in 2003</td>
<td>130 (19)</td>
<td>113 (17)</td>
<td>0.1425</td>
</tr>
<tr>
<td>% reduction</td>
<td>37.3 (3.5)</td>
<td>40.7 (3.4)</td>
<td>0.5131</td>
</tr>
</tbody>
</table>

* t test.
†Percentage was calculated by subtracting each 2000 value from 2003 value divided by 2000 value (mean [SE]).

**Policy implication**

- Employers should give consideration to the implementation of a programme for anti-smoking and reinforcing hygienic behaviour as well as the proper use of personal protective equipment to reduce lead intake among workers.

![Figure 1](http://example.com/figure1.png)

**Figure 1** Yearly changes of BPb during 2000–03 among the current smoking and ex- or never smoking workers.

of wearing protective masks and gloves, and hand and face washing before meals during on-duty hours, responses were “always”, “often”, or “never”. Answers were confirmed by physician’s interview. In the analysis of the indicators for hygienic behaviour, the answers were scored with 2 points for “never”, 1 point for “often”, and 0 points for “always”. Total points for the four behavioural questions were distributed from 0 to 6 points; there were no scores of 7 or 8 points. Based on the total points, subjects were classified into three groups: group A answering “always” for all four questions (total score 0; excellent group); group B answering “always” for three and “often” for one question (score 1; good group); and group C for the other subjects (score 2 to 6; poor group).

Employers should give consideration to the implementation of a programme for anti-smoking and reinforcing hygienic behaviour as well as the proper use of personal protective equipment to reduce lead intake among workers.
behavioural group (p = 0.717) or interaction effect between smoking and hygienic behavioural groups (p = 0.584).

DISCUSSION
The workers of the plant had received intensive health education since 2000 and had made some progress in reducing the levels of BPb and FEP up to 2003. In this study, the magnitude of these reductions was higher in ex- or never smokers than in current smokers. The proportion of “excellent” hygienic workers (group A) among the current smokers was the same as that among the ex- or never smokers (30/62 (48%) versus 20/43 (47%)). Although there may be an overestimation for the self-reported “excellent” rating, it is unlikely to occur depending on their smoking status. In most workers who smoked, the influence of excellent hygienic behaviour could not be reflected; there still seems considerable room for improvement of BPb levels independent of ambient air levels of lead. Intervention over workers’ behaviour should be devoted to increasing workers’ knowledge of smoking hazards and promoting smoking cessation in the workplace.

Although the reduction of BPb was not as distinct as that in FEP on average, the BPb differences between 2000 and 2003 were statistically significant. In spite of the health education, FEP in some of the workers increased retrogressively over the three years, although the individual data are not shown in the present study. FEP reflects recent exposure sensitively, with the result that its value might fluctuate temporarily with inter- and intra-individual factors.

BPb reflects body burden in proportion to the lead storage in the skeletal system (biological half time 1–10 months). Therefore BPb may be a more reliable indicator for biological monitoring in long term interventions such as this study.

It has been recognised that good equipment and cleanliness in the workplace will contribute to reduce the exposure to toxic substances. Our results suggest that no smoking in the workplace contributed to the improvement of BPb. In contrast, even the excellent hygienic behaviour (wearing masks and gloves daily and washing hands and face before every meal) had no effect on BPb if the workers smoke. A positive relation between smoking and BPb levels has been found in some studies.\(^5\)\(^,\)\(^6\) The mechanisms could be mainly attributed to the contamination of cigarettes by workers’ fingers,\(^7\)\(^,\)\(^8\) and partially to the impairment of lung clearance mechanisms by smoking.\(^9\)\(^,\)\(^10\) Smoking may act as a vector for lead to be transferred from face and hand to mouth.\(^1\) It is possible to ingest lead via contaminated cigarettes and fingers when workers smoke or simply touch their mouth. Thus the restriction of smoking with the promotion of hand washing could reduce the unnecessary uptake of lead in the workplace.

Besides smoking, lead intake might be influenced by the hygienic behaviour of workers. In the excellent hygienic behaviour group, their FEP tended to be lower over the three years compared with the poor behaviour group. Although the results showed no significant difference, possibly due to the small number of the poor group (n = 15 for current smokers and n = 7 for ex- or never smokers), the hygienic behaviour seemed to modify the biological monitoring parameters of lead, especially in ex- or never smoking workers. It was shown in previous studies that workers with higher levels of surface lead on their hands had higher BPb,\(^1\)\(^,\)\(^2\) and the frequency of hand-mouth or hand-nose touching became the significant modifier of the BPb.\(^1\) In another study the habit of eating with bare hands and fingers explained the variance of 40% in BPb among lead-acid battery workers.\(^2\) We support the idea that the differences in hygienic behaviour at work explain the degree of the reduction of BPb and FEP to some extent. However, the data of lead-in-air levels (APb) were available only in 2001 and 2003, thus our study has limitations in that the results could not be evaluated because of the possible confounding effect of APb during 2000–03. Further study with personal air sampling would be needed to estimate the contribution of APb to the observed findings.

Elemental lead and inorganic lead compounds are absorbed through inhalation or ingestion. Pulmonary absorption is efficient, particularly if particle diameter is <10 \(\mu\)m. For diameters >10 \(\mu\)m, lead enters the body by ingestion. Thus ingestion related behaviour may have an important impact on biological monitoring parameters of lead. For example, the workers who smoked in their workplace could

Table 2 Frequency of personal hygienic behaviour and number in each hygienic group

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Always</th>
<th>Often</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>During working hours</td>
<td>97 (92%)</td>
<td>7 (7)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Wearing masks</td>
<td>88 (84%)</td>
<td>14 (13)</td>
<td>3 (4)</td>
</tr>
<tr>
<td>Before eating during on-duty hours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washing hands</td>
<td>98 (93%)</td>
<td>6 (6)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Washing face</td>
<td>55 (52)</td>
<td>37 (35)</td>
<td>13 (12)</td>
</tr>
<tr>
<td>Hygienic grouping</td>
<td>A (excellent)</td>
<td>B (good)</td>
<td>C (poor)</td>
</tr>
<tr>
<td>Summary of the above 4</td>
<td>Always = all 4</td>
<td>Always = 3, Often = 1</td>
<td>Others</td>
</tr>
<tr>
<td>n = 50 (48)</td>
<td>n = 33 (31)</td>
<td>n = 22 (21)</td>
<td></td>
</tr>
<tr>
<td>Number of current smokers within each group category</td>
<td>30 (60)</td>
<td>17 (52)</td>
<td>15 (68)</td>
</tr>
</tbody>
</table>
have picked up dust containing lead from their contaminated cigarettes and/or work clothes with their naked hands. The ex- or never smoking workers who keep their hands clean could reduce hand-to-mouth transfers of lead. Although generalisation to all workers is not justified, measurement of anti-smoking and hygienic behaviour by a routine checklist may be helpful to alleviate the absorption of lead through hand and mouth contamination.

In conclusion, the findings suggest that smoking behaviour of workers increases the risk of lead exposure in the workplace. Employers should consider not only engineering controls or replacement of processes, but also personal health education to prevent lead exposure among the workers. The implementation of a programme for anti-smoking and reinforcing hygienic behaviour as well as the proper use of personal protective equipment could be effective for the reduction of lead intake, especially for workers who smoke frequently.

ACKNOWLEDGEMENTS

The authors thank Drs Katsuyuki Murata, Miwako Dakeishi, and Toyoto Iwata for their assistance during the field work. This study was supported by grant-in-aids for scientific research from the Japan Ministry of Education, Science and Culture.

Authors’ affiliations
K Karita, M Nakao, K Ohwaki, Y Yamanouchi, M Nishikitani, K Nomura, M Sato, E Yano, Department of Hygiene and Public Health, Teikyo University School of Medicine, Tokyo, Japan

Competing interests: the authors declare they have no competing financial interests

Table 3  Mean (SE) values of reduction in BPb and FEP between 2000 and 2003 stratified by smoking and hygienic behaviour groups

<table>
<thead>
<tr>
<th>Hygienic behaviour</th>
<th>Subtraction 2003 data from 2000 data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Ex- or never smokers</td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>20</td>
</tr>
<tr>
<td>Group C</td>
<td>7</td>
</tr>
<tr>
<td>Smokers</td>
<td></td>
</tr>
<tr>
<td>Group A</td>
<td>30</td>
</tr>
<tr>
<td>Group C</td>
<td>15</td>
</tr>
</tbody>
</table>

*Two way analysis of variance (ANOVA) showed a significant difference between smokers and ex- or never smokers (p = 0.0084), but no significant variation between A (hygienic excellent group) and C (poor group) (p > 0.05).

REFERENCES
17. Askín DP, Volkman M. Effect of personal hygiene on blood lead levels of workers at a lead processing facility. Am Ind Hyg Assoc J 1997;58:752–3.
Blood lead and erythrocyte protoporphyrin levels in association with smoking and personal hygienic behaviour among lead exposed workers
K Karita, M Nakao, K Ohwaki, Y Yamanouchi, M Nishikitani, K Nomura, M Sato and E Yano

Occup Environ Med 2005 62: 300-303
doi: 10.1136/oem.2004.019513

Updated information and services can be found at:
http://oem.bmj.com/content/62/5/300

These include:

References
This article cites 13 articles, 1 of which you can access for free at:
http://oem.bmj.com/content/62/5/300#BIBL

Email alerting service
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/