Blood lead in U.K. children – time for a lower action level?

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ABSTRACT

1. Blood lead measurements in samples collected from 660 London schoolchildren during 1991 to 1992 suggest that the blood lead values in children in the U.K. are decreasing.

2. Geometric mean values for blood lead were 0.18 (range 0.05–0.71) μmol/l [3.7 (1.0–15.0) μg/dl]. Analysis of variance showed differences between ethnic groups, sex and schools. An age-matched subset of 148 children was compared with 136 children from an earlier study in 1986 and 1987. Trend analysis of the geometric mean lead values showed a negative slope (b = −0.484, P < 0.0001), with maximum values of 0.81, 1.00, 0.71 and 0.43 μmol/l (17, 21, 15 and 9 μg/dl) for the years 1986, 1987, 1991 and 1992 respectively.

3. It is recommended that children in the U.K. being investigated for anaemia, pica, recurrent abdominal pain or a high-risk environment should have blood lead values measured and that the action level for blood lead in children should be decreased from 1.19 μmol/l to 0.48 μmol/l (from 25 μg/dl to 10 μg/dl).

4. Guidance is offered to clinicians and other health professionals investigating excessive lead exposure.

INTRODUCTION

The toxic effects of lead have been recognized for many years [1]. While there is general agreement about the level that is likely to produce acute illness, the significance of lower levels remains controversial [2]. However, recent meta-analysis supports the conclusion that low-level lead exposure has a measurable effect on children’s IQ [3,4].

Many clinicians appear uncertain of the implications of reported blood lead levels, particularly since the units of measurement for lead have changed from μg/dl to μmol/l (SI units). This has also been reported in the U.S.A. [5]. There appears to be a need for guidance to clinicians and other health-care professionals who investigate for excessive lead exposure and require advice on when to call for further action.

Blood samples were obtained during the years 1991 to 1992 from a group of inner London schoolchildren who were taking part in a study to ascertain the incidence of abdominal pain [6]. Blood lead levels were measured as part of this study and the values compared with the results obtained in an earlier study [7] that covered the years 1983 to 1988, before and after the phase down of lead in petrol in January 1986.

The mean blood lead levels in a subset of 148 children from this study who were ≤ 7 years of age at the time of blood sampling were compared with those obtained from 136 children during 1986 and 1987 in the previous study.

SUBJECTS AND METHODS

Children were enrolled in the two studies from schools in one inner London neighbourhood by questionnaires distributed by schools to the parents, after District Health Authority ethics committee approval. The first study

Key words: action level, blood lead, children.
Abbreviation: ANOVA, analysis of variance.
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began in November 1983 and finished in January 1988, although only samples collected during November 1986 and November 1987 were compared with the samples from the second study, which covered the years 1991 and 1992. The questionnaire used in the second study was distributed to the parents of 1472 children and 1007 completed questionnaires were returned. This questionnaire was designed specifically to ascertain the incidence of abdominal pain in schoolchildren [6], and to check for correlation with gender, age, ethnicity, residential area, familial occurrence and school attended. These factors were in accordance with the evaluation criteria suggested as essential by the IUPAC and TRACY reports for a study of this type [8,9]. Agreement to give a blood sample was obtained in 660 cases. Blood was taken by venepunctures after the application of EMLA local anaesthetic cream to reduce the pain produced, collected into lithium–heparin-containing tubes, mixed and stored at 4 °C for lead determination. These tubes, which were used in both studies, were tested for trace metal contamination and none was found. Specimens from 640 children, 383 boys and 257 girls, were adequate for analysis. The mean age of the whole group was 9.2 (range 4.9–13.9) years. Ethnic groups were assigned at the time of blood taking: 534 (83.4%) were classified as Caucasian, 46 (7.2%) as Afro-Caribbean, 33 (5.2%) as Oriental and 26 (4.1%) as Indian subcontinent. One child was of Polynesian extraction.

A subset of 148 children were compared with 136 children from a previous study who attended schools in the same London area and were between 5 and 7 years of age in 1986 or 1987. It was necessary to use an age-matched subset for this comparison, due to the greater age range in the present study as compared with the earlier one.

### Blood lead

Samples were stored at 4 °C for no longer than 7 days, before analysis for lead using an IL Video 11 spectrophotometer and IL 655 furnace atomizer with Fastac II auto-sampler (Thermo Electron Ltd, Warrington, U.K.). The method was based on that of Stoeppler et al. [10]. A single matrix-matched calibration curve which was prepared for each analysis was used to calculate concentrations. Lead standards, 0, 0.19, 2.38, 3.57 and 4.76 µmol/l (0, 25, 50, 75 and 100 µg/dl), were prepared from Merck Spectrosol Lead standard for atomic absorption spectroscopy, and all standards, blanks and samples were analysed in duplicate with two replicates per sample. Internal blood controls with naturally occurring levels of lead were analysed throughout the studies. For the 1986–1987 study, three samples with levels of 0.33, 0.86 and 2.38 µmol/l (7, 18 and 50 µg/dl) were included in each analysis [7]. The between-batch, (inter-assay) results for the 1991–1992 study were 0.29 ± 0.04 µmol/l (6.1 ± 0.9 µg/dl); 14.8% coefficient of variation, n = 20. Reconstituted lyophilized control blood samples for metals [Boehring-Hocheht (U.K.) Ltd, Hounslow, U.K.] were used for both studies at three levels: −0.71, 1.90 and 3.48 µmol/l (15, 40 and 75 µg/dl) with a reproducibility of < 10% (intra-assay coefficient of variation). The laboratory participated in three external quality assurance schemes for blood lead. Results obtained from these schemes were as follows, Blood Lead Proficiency Testing, Centers for Disease Control, Atlanta, Georgia, State Laboratory of Hygiene (1991–1992), all values were within target ranges; U.K. National External Quality Assessment Scheme (NEQAS) for lead in blood, Queen Elizabeth Hospital, Birmingham, for 1986–1987, the Mean Running Variance Index Score (MRVIS) = 14 (MRVIS = 44 for all participants combined); for 1991–1992, MRVIS = 24 (MRVIS = 44 for all participants combined); Trace Element Quality Assessment Scheme (TEQAS), Analytical Unit, Robens Institute, University of Surrey, U.K., for 1986–1987: performance score: 69.9, median score: 22.9, ranking: first out of 34 laboratories, for 1991–1992, blood lead cumulative scores (CUSUM) = 85.8, which was greater than the minimum acceptable value of CUSUM = 20.

### Statistical analysis

The statistical package SPSS for Windows was used for all calculations. Non-parametric statistics were used for analysis of data where the distribution was skewed. The use of subsets selected by age did not affect the rate of false-positive findings (Professor Michael Healy, personal communication).

### RESULTS

The response rate was 68.4%; 1007 of the original 1472 questionnaires were returned. Participation rate, that is, the number of parents who agreed to a blood sample being taken from their child was 65.5%, calculated from the returned questionnaires, or 44.8% of the original number sent out. There were no significant differences between the sex ratio, age, race or school attended for the responding group who refused and the group who agreed to blood sampling.

Due to the positively skewed distribution of the blood lead data, geometric mean values (log means) were calculated for this study. Blood lead values were available for 630 children. The geometric mean lead value for this population was 0.18 µmol/l (3.7 µg/dl), median = 0.19 µmol/l (4.0 µg/dl), mean = 0.20 µmol/l (4.1 µg/dl), range 0.05–0.71 µmol/l (1.0–15.0 µg/dl) (Table 1). The greatest value measured was 0.71 µmol/l (15.0 µg/dl), and in five cases (0.8%) the values were ≥ 0.48 µmol/l (10.0 µg/dl). The geometric mean lead value was greater for boys than for girls, 0.19 and 0.17 µmol/l (3.9 and
Table 1  Blood lead values in the study group, showing the difference between the mean levels in girls and boys

AM, arithmetic mean; GM, geometric mean. Mann–Whitney U-test * and ** significant difference between the means, 2-tailed P = 0.0005.

<table>
<thead>
<tr>
<th>Age range (years)</th>
<th>Sex</th>
<th>No.</th>
<th>AM ± S.D. (µmol/l)</th>
<th>GM ± S.D. (range)</th>
<th>Median (µmol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.9–13.9</td>
<td>Both</td>
<td>629</td>
<td>0.19 ± 0.08</td>
<td>0.18 ± 0.07</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.1 ± 1.6 µg/dl</td>
<td>3.7 ± 1.5 (1.0–15.0) µg/dl</td>
<td>4.0 µg/dl</td>
</tr>
<tr>
<td>5.0–13.9</td>
<td>Males</td>
<td>380</td>
<td>0.20 ± 0.08</td>
<td>0.19 ± 0.07</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.2 ± 1.7 µg/dl</td>
<td>3.9 ± 1.5 (1.0–15.0) µg/dl</td>
<td>4.1 µg/dl</td>
</tr>
<tr>
<td>4.9–11.8</td>
<td>Females</td>
<td>249</td>
<td>0.18 ± 0.07</td>
<td>0.17 ± 0.07</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.8 ± 1.5 µg/dl</td>
<td>3.5 ± 1.5 (1.0–10.0) µg/dl</td>
<td>3.9 µg/dl</td>
</tr>
</tbody>
</table>

Table 2  Distribution of blood lead values by sex and school attended

GM, geometric mean. The mean values for blood lead for each school, after correction for sex of child, showed significant differences (P < 0.0001), using the Kruskal–Wallis one-way ANOVA.

<table>
<thead>
<tr>
<th>School</th>
<th>Age range (years)</th>
<th>Blood lead (µmol/l)</th>
<th>No.</th>
<th>Age range (years)</th>
<th>Blood lead (µmol/l)</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5.4–11.5</td>
<td>0.20 ± 0.07 (0.09–0.43)</td>
<td>29</td>
<td>5.5–11.3</td>
<td>0.15 ± 0.06 (0.09–0.33)</td>
<td>28</td>
</tr>
<tr>
<td>B</td>
<td>5.1–11.5</td>
<td>0.22 ± 0.06 (0.09–0.33)</td>
<td>25</td>
<td>5.6–11.3</td>
<td>0.22 ± 0.07 (0.09–0.43)</td>
<td>18</td>
</tr>
<tr>
<td>C</td>
<td>5.0–11.5</td>
<td>0.19 ± 0.07 (0.05–0.43)</td>
<td>46</td>
<td>4.9–11.8</td>
<td>0.17 ± 0.07 (0.09–0.34)</td>
<td>74</td>
</tr>
<tr>
<td>D</td>
<td>5.4–11.7</td>
<td>0.22 ± 0.06 (0.14–0.40)</td>
<td>29</td>
<td>5.5–11.7</td>
<td>0.20 ± 0.06 (0.14–0.48)</td>
<td>28</td>
</tr>
<tr>
<td>E</td>
<td>5.3–11.6</td>
<td>0.18 ± 0.07 (0.05–0.55)</td>
<td>59</td>
<td>5.4–11.4</td>
<td>0.15 ± 0.07 (0.05–0.34)</td>
<td>41</td>
</tr>
<tr>
<td>F</td>
<td>5.2–11.5</td>
<td>0.17 ± 0.07 (0.05–0.34)</td>
<td>51</td>
<td>5.1–11.6</td>
<td>0.15 ± 0.07 (0.05–0.34)</td>
<td>65</td>
</tr>
<tr>
<td>G</td>
<td>8.6–13.9</td>
<td>0.19 ± 0.07 (0.05–0.71)</td>
<td>145</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.5 µg/dl) respectively (Mann–Whitney U-test showed a significant difference, 2-tailed P = 0.0005). There was no significant difference between Caucasians and non-Caucasians as a whole; the geometric mean lead value for Caucasians was 0.18 µmol/l (3.8 µg/dl) and for non-Caucasians 0.17 µmol/l (3.6 µg/dl), Mann–Whitney U-test, 2-tailed P = 0.173. However, comparison of individual ethnic groups showed a difference [Kruskal–Wallis one-way analysis of variance (ANOVA), χ² = 13.64, P = 0.003], with the greatest geometric mean lead value recorded for those classified as Afro-Caribbean, 0.20 µmol/l (4.1 µg/dl) and the least for those classified as Indian subcontinent, 0.15 µmol/l (3.1 µg/dl).

There was no significant difference between the blood lead values in different age groups (ANOVA F = 1.08, P = 0.38). Analysis of variance suggested that there was a difference in the blood lead values among pupils from different schools: Kruskal–Wallis one-way ANOVA, χ² = 30.1, P < 0.0001. Analysis of the data for girls and boys separately showed no significant difference between blood lead values in boys (χ² = 14.5, P < 0.02), but there was a significant difference between the blood lead values in girls (χ² = 18.3, P < 0.003) from different schools (Table 2). The range of geometric means for blood lead classified by school attended was 0.15–0.22 µmol/l (3.1–4.6 µg/dl).

Figure 1  Blood lead levels in London children in 1986/87 and 1991/92
Values are geometric means ± 95% confidence limits.
Trend analysis of the geometric mean lead values in 1986, 1987, 1991 and 1992 for boys and girls aged between 5 and 7 years of age (Figure 1), showed a significant negative trend \( (b = -0.484, P < 0.0001) \), with maximum values of 0.81, 1.00, 0.71 and 0.43 \( \mu \text{mol/l} \) (17, 21, 15 and 9 \( \mu \text{g/dl} \)) for the years 1986, 1987, 1991 and 1992 respectively.

DISCUSSION

The impact of low-level lead exposure on children’s development has been a matter of discussion for some time [11]. Recent meta-analysis supports the conclusion that low-level lead exposure has a measurable, although small effect on children’s IQ [3,4,12]. Since such low-level lead exposures are believed to be two orders of magnitude greater than those in pre-industrial populations [13], there has been continuing interest in identifying ways of reducing childhood exposure to lead.

Although primary prevention has been suggested as the only appropriate strategy, the difficulties in implementing such an approach are likely to be considerable [14]. There is also doubt about whether the resources needed to reduce lead exposure to ever lower levels are likely to be available in the light of competing priorities [15], so that identification of risk groups may be a more realistic aim [16]. One possible technique is the use of ‘action levels’, that is, levels above which intervention is indicated, such as examination of the child’s environment for remediable sources of exposure.

Action levels for lead have been progressively reduced in many countries. The current U.K. advisory action limit is 1.19 \( \mu \text{mol/l} \) (25 \( \mu \text{g/dl} \)) [17], having been reduced from 1.67 \( \mu \text{mol/l} \) (35 \( \mu \text{g/dl} \)) in 1982 [18]. Other countries, notably the U.S.A. and Australia, have reduced their action levels to 0.48 \( \mu \text{mol/l} \) (10 \( \mu \text{g/dl} \)) [19]. One concern in reducing the action level is the possible increase in the resources needed to implement such a change, perhaps diverting resources from other areas. In the U.S.A., the recommendation for universal lead testing of all children under the age of 6 years was not implemented in many parts of the country [20] and was recently abandoned in favour of a ‘screening initiative to address problems in core problem areas’ [21]. On the other hand, since many sources of environmental lead have declined, for example, additives in petrol or solder in tin cans, a constant action level may become insensitive to variations in those sources that remain. These sources include old paint of high lead concentration, house dust or contaminated soil that may be ingested by young children, especially those with pica [22]. The water supply in certain areas may be above the recommended maximum lead concentration [17,23], while in communities adjacent to congested traffic conditions, the atmosphere may contain raised lead levels [24].

These studies of inner London schoolchildren in the age range 5–7 years revealed a significant decrease in blood lead values between the years 1986 and 1992. These findings agree with other studies in the U.K. reported by Delves et al. [25] and Watt et al. [23]. No child in the present study had a blood lead > 0.71 \( \mu \text{mol/l} \) (> 15.0 \( \mu \text{g/dl} \)). This study showed that although there were statistically significant differences between sexes, ethnic groups and schools, the magnitude reported was unlikely to have had clinical or public health significance. Moreover, while the differences between the ethnic groups and the schools could be a reflection of social class [26], other cultural and environmental factors may also have been involved.

The blood lead values recorded do allow some estimate of the possible impact of lowering the action level in the U.K. The rationale quoted in the Department of the Environment circular [18] was that 1.67 \( \mu \text{mol/l} \) (35.0 \( \mu \text{g/dl} \)) represented the 95th percentile for blood lead levels in 1982. In the present study, the 95th percentile was 0.33 \( \mu \text{mol/l} \) (7.0 \( \mu \text{g/dl} \)); however, 99.2% of the children had blood lead values within the range 0.00–0.48 \( \mu \text{mol/l} \) (0.0–10.0 \( \mu \text{g/dl} \)), and the remaining 0.8% of these children were within the range 0.48–0.71 \( \mu \text{mol/l} \) (10.1–15.0 \( \mu \text{g/dl} \)). This would suggest that a reduction in the action level for lead in the U.K. to 0.71 \( \mu \text{mol/l} \) (15 \( \mu \text{g/dl} \)) could be implemented for schoolchildren without resource implications. Moreover, 99.2% of the study population had blood lead values of < 0.48 \( \mu \text{mol/l} \) (10 \( \mu \text{g/dl} \)), so that a further reduction in the action level to this value should be considered.

The decrease in prevailing blood lead levels in the population has resulted in an increasing disparity between the upper limit of the 95th centile and the blood lead concentration which should trigger an administrative response. Interpretation of blood lead levels requires recognition of which levels are anomalous compared with those found in the local population. The prevailing local conditions need to be known, as it may not be possible to extrapolate from one country or area to another. A child whose blood lead is greater than the upper limit of the 95th centile merits investigation. The following approach to children with anomalous blood lead levels is therefore proposed. After confirming that the blood lead level is raised, the blood lead should be monitored at appropriate intervals to ascertain whether the level is static, decreasing, indicating past exposure, or increasing, indicating present exposure. The duration of these intervals will depend on the magnitude of the initial blood lead value and expert clinical advice. Should the blood lead be increasing, an appropriate investigation needs to be implemented to identify the source of the exposure, to prevent potential progression to a clinically significant level. In certain circumstances, the pattern of blood lead levels in family members living at the same address needs to be checked.
CONCLUSION

The present action level for lead of 1.19 µmol/l (25 µg/dl) is inappropriate for schoolchildren and should be reduced to 0.48 µmol/l (10 µg/dl). Screening is contraindicated, not on the basis of cost, but due to the large number of negative results that would be obtained, the trauma of blood sampling, the potential variation of blood lead with age, and the burden of the workload on those laboratories equipped to analyse blood lead levels.

Considering that 99% of this group of London schoolchildren have blood lead levels below 0.48 µmol/l (10 µg/dl), a child with a level above this value should be investigated to find the cause. Since there is a possibility that IQ is affected when blood lead levels are > 0.48 µmol/l (10 µg/dl), and that this may be reversed by lowering the blood lead, health-care workers should be aware of the need for further investigation when blood lead values > 0.48 µmol/l (10 µg/dl) are reported.

The following procedures are recommended: early confirmation of a raised blood lead level, appropriate monitoring to check whether the levels are static, rising or falling, identification of the source of the exposure and examination of other family members residing at the same address.

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