The Uptake of Lead by Children in Differing Environments

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Balance studies have been performed for lead upon eight healthy children in three different home environments and upon eight children with inborn errors of metabolism in hospital (consuming two different types of synthetic diet). The balances were for 3 days and involved the use of metal-free diapers where indicated. The concentration of lead in all the samples was determined by atomic absorption spectroscopy after suitable sample preparation.

In addition, the total population of children under the age of 16 living in a working class area exposed to undue amounts of lead was examined in an attempt to determine whether their mental development had been affected. Blood lead levels, general intelligence, reading ability, and rate of behavior disorder were measured.

The results of the balances showed that the mean daily intake of lead in both groups of children was lower than previously recorded figures, being lowest of all in the breast-fed infant. The healthy group absorbed a mean value of 53% and retained 18% of the dietary intake and there was no relationship to age or month of the year of study. The children with inborn errors showed a significantly lower percentage absorption of lead.

The preliminary results of the population survey showed that distance from the polluting lead source was related to blood lead level, but no relationship could be found between blood lead level and any measure of mental function.

Introduction

There is increasing evidence that children, and the young of most species, are more prone to lead intoxication than adults (*1*, *2*). Barltrop (*3*) has suggested that this may be due to the oral exploration by children of their environment. Pentschew and Garro (*4*) considered that there was an increase in susceptibility to lead of the young animal. Kostial, Simmonovic, and Pisonic (*5*) showed that the uptake of lead from the intestine of new born rats was fifty times that of the adult rat.

We have performed 11 balance studies on eight healthy children in their different home environments and eitht children with inborn errors of metabolism living in hospital. Although the balances were carried out to determine the requirements for trace metals of the children on synthetic diets, this provided us with an opportunity to assess the intake and excretion of lead by children in different environments.

In addition, there are suggestions that low-level lead intoxication leads to subtle changes in behaviour and mental development in young children. David et al. (*6*) showed evidence of a greater lead load in overactive children as compared with controls from the same population. Also Burdé and Choate (*7*) reported poor fine motor control in children with pica and evidence of mild lead intoxication. However, Kotak (*8*) was unable to demonstrate any relationship between behavioral or intellectual disturbances and lead ingestion.

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We have been associated with a unique study in a population exposed to varying amounts of lead in the environment emitted from a smelting factory (*9*). In this study the place of residence (past and present), blood lead levels, intelligence, reading ability, and behavior were all examined for possible relationships.

Balance Technique

Subjects

Group A constituted A control group of eight healthy children whose ages ranged from 3 months to 8½ years. Three children were at one of our homes, two at another and the other three in an institution; all were on a free diet. The youngest was breast fed at the time of the balance.

Group B was a group of six patients with inborn errors of metabolism on aminogram (Allen and Hanbury Ltd.) and mineral supplements (ages 3 months to 8½ years).

Group C comprised two neonates with phenylketonuria (PKU) on Minafen (Cow and Gate).

Method

Three day balances were performed between markers, "metal-free" diapers being used, where necessary, as described by Alexander and Delves (*10*). Samples were collected, homogenized, and analyzed by atomic absorption spectrometry as described previously (*10*).

Environmental Study

Blood was collected by finger-prick from 476 children in the area, 119 of whom were over 5 years of age, and the lead level determined by the micro-technique devised by Delves (*11*). Children at school received standard tests of intelligence (according to Wechsler) and the Burt graded word reading test. They were also assessed by school teachers as to behavior according to a valid questionnaire.

Results

Balances

Figure 1 shows the daily uptake of lead

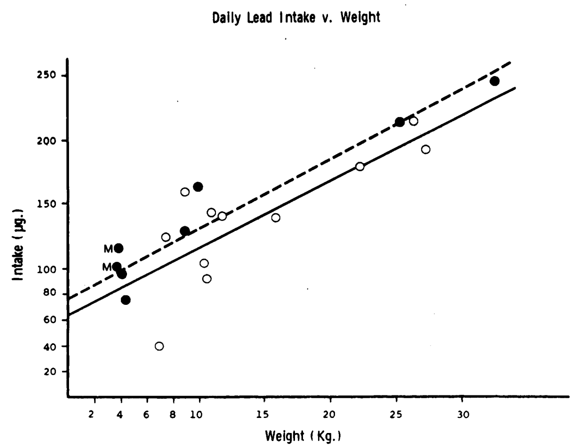

FIGURE 1. Daily lead intake vs. weight.

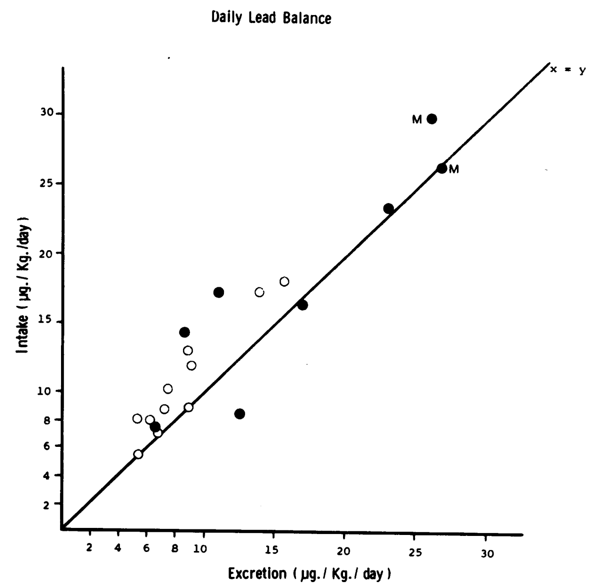

FIGURE 2. Daily lead balance.

by the three groups plotted against weight; Figure 2 gives the daily uptake of lead per kilogram body weight, plotted against excretion for the three groups. The healthy children are represented by the open circles, the children with inborn errors of metabolism by the closed circles (the two phenylketonurics on Minafen are denoted by M).

The solid regression line in Figure 1 applies to the healthy children, the broken line to the children on synthetic diets. The individual lead balances for all children are

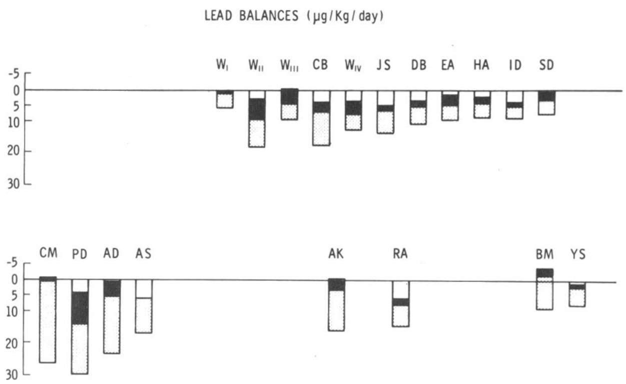

FIGURE 3. Individual lead balances.

represented as histograms in Figure 3, drawn according to the conventions used by Albright et al. (*12*). The healthy children (group A) appear on the top line in chronological order; group C is the first two histograms on the lower line, the remainder represent group B. The mean daily intake, excretion, absorption and retention of lead by the other groups are listed in Table 1.

The daily intake of lead increased with age from 40 µg in the breast-fed infant to 210 µg at 8½ years (Fig. 1). The intake by children on synthetic diets was higher (90 µg at 1 month to 240 µg at 8½ years) but did not differ significantly from the healthy controls. Again, there was no significant difference between the groups when intake per kilogram was plotted against excretion (Fig. 2). The individual balance histograms (Fig. 3) show that lead intake per unit weight was highest in the neonate and that absorption and retention of lead were also higher in the younger children, with the exception of the breast-fed control (W1) and one of the PKU children on Minafen (CM).

These observations are confirmed by the mean daily values for the three groups (Table 1). The children on the aminogram diet (group B) had a higher mean daily intake and excretion of lead, but this did not differ significantly from the healthy (group A) children. The fecal excretion by the children in group B, however, was significantly greater than that in the normals. Both intake and excretion of lead by group C was higher still and became statistically significant ($P < 0.01$).

The mean absorption by group A expressed as a percentage of the intake was 53% compared with that of group B children of 24%. The difference is statistically significant ($P < 0.01$). The mean daily absorption by group C (26%) did not differ significantly from that of the healthy (group A) controls. Daily retentions of lead for all three groups did not differ significantly.

Environmental Study

Whole blood lead concentrations of preschool children in relation to distance from the smelting works is shown in Figure 4.

The relationship between distance from the works and intelligence and behavior is shown in Figures 5 and 6, respectively; the relationship between current lead level and intelligence and behavior is shown in Table 2.

Table 2. Current lead level, intelligence, and behavior in school age children.

Lead level, µg/100 ml	Mean IQ	% disturbed	*N*
60+	105.8	16.6	6
50+	104.8	16.6	6
40+	101.2	19.4	31
39−	100.7	25.1	172

Figure 4 shows that the nearer the child lived to the source of lead, the higher the blood lead level. There was a significant dif-

Table 1. Mean daily intake and excretion of lead.

Subjects (No.)	Intake total, µg/kg (±S.D.)	Excretion, µg/kg (±S.D.)			Absorption		Retention	
		Total	Urine	Feces	Amount, µg/kg (±S.D.)	% Intake	Amount, µg/kg (±S.D.)	% Intake
Aminogran (6)	10.62 ± 4.03	8.56 ± 3.31	3.43 ± 1.52	5.14 ± 2.59	5.48 ± 1.85	53	2.05 ± 1.39	18
Minafen (2)	14.53 ± 5.91	13.05 ± 5.99	2.50 ± 1.92	10.55 ± 4.32	3.98 ± 3.40	24 [a]	1.48 ± 3.90	10
Controls (11)	28.15 ± 2.62	26.25 ± 0.35	5.75 ± 6.29	20.50 ± 6.65	7.65 ± 9.26	26	1.90 ± 2.97	7

[a] Significantly different from the control value ($P < 0.01$).

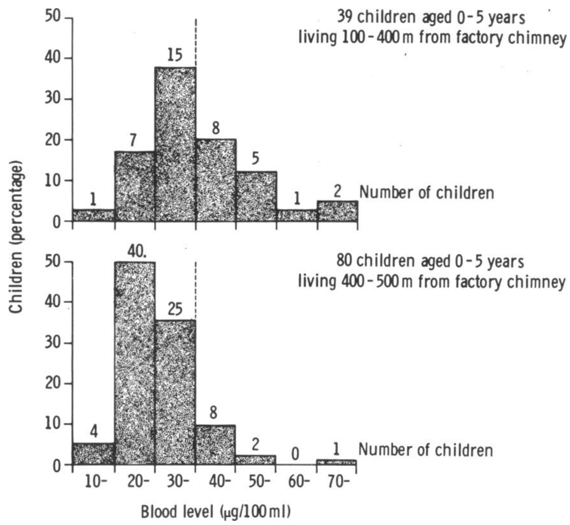

FIGURE 4. Whole blood lead concentrations related to distance from smelting works.

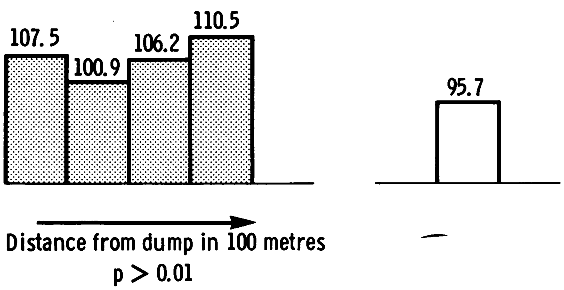

FIGURE 5. Intelligence in school age children vs. residence in first two years of life.

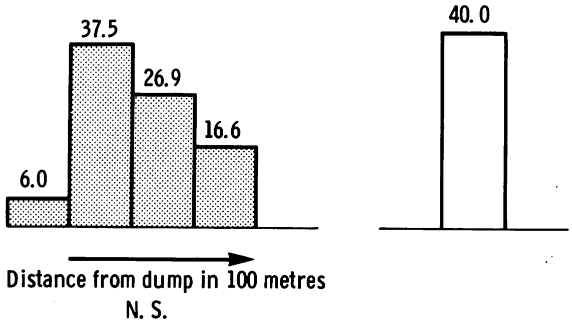

FIGURE 6. Overactivity in school age children vs. residence in first two years of life.

ference between the mean levels of blood lead of children living up to 400 m away and that of children who lived further away. It can be seen from Figures 5 and 6 and Table 2 that there was no significant correlation between intelligence and behavior and either lead level or current address in the first 2 years of life. Indeed, those children who had moved into the area after the second year of life appeared to be of lower intelligence and have a higher degree of behavior disorder.

Discussion

The very low intake of lead by the breast-fed infant has been reported previously (*3*) and may be explained by a natural filter mechanism. The daily intake of lead by all the children studied increases linearly with age but never reaches the value of 300 μg reported by Kehoe (*13*) and presumed by Barltrop (*3*) to be the maximum daily intake for children.

The significantly higher fecal excretion by the children in group B is responsible for their significantly lower absorption and is probably related to a difference in the constitution of the diets. We have reported elsewhere (*14*) that the calcium/phosphorus ratio in the diets of group B is significantly higher than that of control diets (1.14 for group B; 0.76 for group A). The healthy controls in our series absorbed 53% of the ingested lead. This figure is very much higher than previous reports by Kehoe, for adults, of zero (*13*) and 5%% (*15*), but is of the same order as the absorption of lead of 55% by newborn rats reported by Kostial et al. (*5*).

This finding may go some way to explain the increased susceptibility of young children to exposure to lead and should be taken into account when calculating safety limits for children.

In the environmental study the positive correlation between blood lead levels and proximity to the smelting works was expected. Even though 43 out of the 257 school children (17%) had blood lead levels greater than 40 there was no correlation with lower intelligence or deviant behavior. It may be that the methods of testing were not sufficiently sensitive to detect more subtle deviations of intelligence or behavior. There is also some anecdotal evidence that the children who moved into the periphery of the field of study belonged to families with greater social problems. Nevertheless, these preliminary results suggest that mild exposure to lead does not produce detectable, adverse mental effects.

Acknowledgement

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