Undernutrition and elevated blood lead levels: effects on psychomotor development among Jamaican children

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Abstract

Objective: We examined whether or not the effect of elevated blood lead levels on children's psychomotor development was modified by their nutritional status.
Design: Anthropometry, developmental quotients (DQs), blood lead levels and haemoglobin were measured in lead exposed and unexposed children with different levels of nutritional status. Social background and maternal height and verbal intelligence were also measured. Testers, anthropometrists and interviewers established reliabilities with a trainer before the study began.
Setting: Children were from two suburban areas in Kingston, Jamaica. All measurements on the children were carried out at a research unit. Social background and maternal measurements were carried out at the children's homes.
Subjects: The exposed group comprised 58 children (3–6 years) attending the same preschool which was situated in a lead contaminated environment. The unexposed group comprised 53 children attending a nearby preschool without lead contamination.
Results: The exposed children had significantly higher blood lead levels and lower DQs, and their homes had poorer facilities than the unexposed children. The deficit in DQ was greater (10.6 points) among children with weight for height less than −1 SD (National Center for Health Statistics references) than among better nourished children (2 points).
Conclusions: Undernourished children exposed to lead may have more serious developmental deficits than better nourished children.

Keywords
Lead
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Undernutrition remains an important public health problem in developing countries[1]. Many researchers have demonstrated an association between undernutrition and poor psychomotor development in young children[2], and poor levels of intelligence and school achievement in later childhood. In countries with high levels of undernutrition, this has serious implications for national development.

Additionally, several longitudinal studies indicate that prenatal and childhood exposure to lead is associated with deficits in children's cognition[3–7], although some controversy remains over the magnitude of the effects[8]. These studies have generally been conducted in developed countries and often with groups of middle to high socioeconomic status. In one study with low-income families in the USA, interaction with socioeconomic status suggested that the effects of lead may be greater in children from poorer families[7].

The problem of lead pollution is now greatest in the rapidly expanding cities in developing countries where the use of lead in petrol remains the norm[9]. Undernutrition is also common in the under-5 population in many of these countries[1] and it is possible that undernourished children may be more vulnerable to lead exposure than well-nourished children. There is, however, a lack of data to address this question as little of the research concerning lead and development has been conducted in developing countries. The aim of this study was to compare the psychomotor development of preschool children in a lead contaminated community in Kingston, Jamaica with that of children in a control community and to determine whether the effect of lead on development was modified by the children's nutritional status.

Methods

The sample comprised children who attended a preschool (school KT) which was located on a site contaminated with lead waste and undifferentiated ore

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grade material from a nearby defunct lead mine[10] and where the children were living in a high lead contaminated environment. All children aged 3–6 years attending the school, whose parents gave informed consent, and who had no obvious mental or physical handicap were included ($n = 58$, 26 boys). The sample comprised 92% of children attending the school in the age group. A comparison group of all available children from a preschool in an adjacent community (school AT) were also recruited ($n = 53$, 25 boys). The soil lead levels at this school were within the normal background levels for Jamaica[11] and the comparison community was ranked immediately above the lead exposed community according to the poverty index of the Planning Institute of Jamaica[12].

The children's developmental quotients (DQs) were measured using five subscales of the Griffith's Mental Development Scales—locomotor, hand and eye, hearing and speech, practical reasoning and performance[13]—by one of two testers. Intertester reliability was established before the study began (concurrent agreement on 11 children = 99%), and each tested a similar proportion of children from both groups. Anthropometric measurements were taken using standard techniques[14] and interobserver reliabilities were high ($r = 0.99$). Haemoglobin measurements were made using a Hemocue[15]. Capillary blood samples from a fingerprick were collected on filter paper for subsequent lead content analysis at LeadTech Corporation, New Jersey, using micro blood techniques[16,17]. Special care was taken to avoid contamination. The children's hands were washed by an investigator immediately prior to the fingerprick blood collection, according to the protocol provided by LeadTech Corporation, dried with a paper towel, and did not touch any surface or objects before the samples were taken. All measurements on the children were conducted at the Tropical Metabolism Research Unit.

The children's homes were visited and their caretakers were given a questionnaire to assess their social background. The standard of housing was rated on a nine-point scale in which equal weight was given to water supply, toilet facilities and level of crowding. Household possessions were scored as the sum of the presence of a stove (oil, gas or electric), television, radio and refrigerator (range 0–4). Environmental stimulation was measured using a modified version of the Bettye Caldwell Home Observation for Measurement of the Environment (HOME) inventory[18], and caretakers' verbal intelligence was measured using the Peabody Picture Vocabulary test (PPVT)[19]. All home interviews were carried out by a single researcher whose concurrent agreement with the trainer on 20 interviews before the study began was 98%.

Approval for the study was granted by the Jamaican Ministry of Education, and the Ethical Committee of the University of the West Indies.

Table 1 Developmental levels, social background, nutritional status and blood lead levels of children in school KT (exposed) and school AT (unexposed)

	School KT		School AT	
	Mean	SD	Mean	SD
DQ	94.0	11.0	98.7	10.8*
Housing rating	5.0	2.0	6.6	1.8**
No. of possessions	2.8	1.1	3.1	1.0
Caretaker's PPVT	90.5	20.8	98.7	24.6
HOME	21.2	5.5	21.4	5.6
Height for age (z-score)	−0.3	0.9	−0.04	1.0
Weight for height (z-score)	−0.3	0.9	−0.1	0.8
Haemoglobin (g dl^{-1})	11.3	1.4	11.5	1.2
Lead ($\mu g\ dl^{-1}$)	32.0	13.7	13.5	5.2**

t-test * $P < 0.05$, ** $P < 0.001$

Statistical analyses were conducted using the SPSS for Windows statistical package.

Results

The children's characteristics and social background are shown in Table 1. The children in school KT had significantly lower DQs and came from homes with poorer facilities than the children from school AT. None of the remaining social background variables were significantly different between the groups and there were also no significant differences in nutritional status. As expected the blood lead levels were significantly higher in the children attending school KT.

Multiple regression analyses were conducted to determine the effect of lead exposure on the children's developmental levels controlling for social background, and to examine possible interactions between the measures of nutritional status (height for age, weight for height, haemoglobin) and lead exposure. Children who attended school KT were the exposed group and the children in school AT were the unexposed group. Separate regression analyses were conducted for each of the nutritional variables. In each, the children's age and sex were entered and the following social background variables were offered: housing rating, possessions, caretaker's PPVT and stimulation (HOME). Although some of the social background variables were not significantly different between the groups they were included as potential confounders as they have been shown to be important in other studies of lead and cognition. In the final step, school attended, the measure of nutritional status and the interaction term were entered.

The multiple regression model including weight for height and the interaction term with lead exposure is shown in Table 2. Among children with weight for height ≤ -1 SD[20] the DQs of children in school AT (unexposed) were 10.6 points higher than those in school KT ($P < 0.05$). However, in children with better nutritional status (weight for height > -1 SD) the

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Table 2 Multiple regression of DQ on child characteristics, social background[a] and lead exposure

Variable	B	SE	*P*
Age (mo)	−0.36	0.07	0.001
Sex	2.02	1.71	0.24
No. of possessions	2.70	0.84	0.01
HOME	0.36	0.16	0.05
School[b]	10.57	4.42	0.05
Weight for height[c]	2.07	2.87	0.47
Weight for height × school	−8.60	4.81	0.08

[a] Social background variables offered: housing rating, possessions, caretaker's PPVT, HOME. [b] School KT (exposed) = 0, school AT (unexposed) = 1. [c] Weight for height z-score $\leq -1 = 0$, $> -1 = 1$

difference was only 2 DQ points. In a regression excluding weight for height and the interaction term, the difference between the schools was 3.2 points ($P = 0.058$). There were no significant interactions of lead exposure with height for age or haemoglobin levels.

Discussion

Our results suggest that lead exposure may be more detrimental to undernourished children's development compared with adequately nourished children. The overall effect of lead in this study was comparable to that reported elsewhere[21,22], and was greater in children with weight for height below −1 SD. This cut-off indicates only mild wasting so the difference may be greater in children with severe nutritional deficits.

There were some limitations to the study: the sample size was small, although it comprised almost the entire exposed population. The study design would also have been stronger if it had been possible to recruit exposed and unexposed children from the same school. However, almost all of the children at school KT had elevated blood lead levels, and the comparison group had to be found from another school.

The interaction effect which indicated that the undernourished children were more vulnerable to the effects of elevated blood lead levels was only marginally significant, and the finding needs replication elsewhere. If confirmed, and undernourished children are more vulnerable to lead exposure, the increasing problems with lead pollution in developing countries become of even greater public health significance.

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