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6/7/79

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Ron

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Chuck

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cc: D. R. Diggs
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A. J. Pahnke
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May 31, 1979

To: D. H. Payne

From: E. S. Jacobs ESJ/dg

"LONGITUDINAL CHANGES IN BLOOD LEAD LEVEL IN CHILDREN AND THEIR RELATIONSHIP TO SEASON, AGE, AND EXPOSURE TO PAINT OR PLASTER"

The attached article appeared in the April, 1979 issue of the American Journal of Public Health. I call it to your attention because the article indicates there is little, if any, seasonal change in blood lead levels of children in New York City. In addition, the authors found the major variable in predicting blood lead level change were the child's age at screening and a history of exposure to paint or plaster.

This may be helpful in responding to draft articles by Billick.

ESJ/dmg
Attach.

Longitudinal Changes in Blood Lead Level in Children And Their Relationship to Season, Age, And Exposure to Paint or Plaster

JANE MCCUSKER, MD, DRPH

Abstract: Children screened for lead poisoning in the Brownsville district of New York City in either summer or winter were followed with blood lead tests for approximately six months to one year from screening to measure longitudinal changes in blood lead level and to identify some determinants of the changes. Only minimal evidence was found of the hypothesized summer rise in blood lead level, while the predominant trend seemed to be for blood lead levels to display statistical regression to the mean. In children found to have low to intermediate blood lead levels (<55 μg/100ml) at screening, variables which were found to predict a rise in blood lead level of 10 μg/100ml or greater from winter to summer were under age three and/or exposure to paint or plaster. (Am. J. Public Health 69:348–352, 1979.)

Introduction

Lead poisoning screening programs aim to prevent symptomatic and asymptomatic lead poisoning and its sequelae through the early detection of children with excessive lead absorption, followed by medical and/or environmental intervention. The blood lead test has been in widespread use as a screening test, but its reliability and validity have been questioned.[1] More recently the free erythrocyte protoporphyrin (FEP) test, a measure of the toxic effects of lead on the synthesis of heme, has been advocated as an alternative or supplement to the blood lead test.[1, 2] Reigart and Whitlock[3] evaluated both tests longitudinally in a group of Black children in Charleston, South Carolina and found greater fluctuations in the blood lead than in the FEP level. In general, in children in whom the test results were discordant, (i.e., high FEP and low blood lead level or vice versa), subsequent changes in blood lead level tended to follow the direction suggested by the initial FEP level.

Guidelines for screening programs have gradually reduced the blood lead level cut-off which separates positive from negative test results.[2, 4] Increasing emphasis is placed on the periodic rescreening of "high-risk" children, generally agreed to be children under six years of age who live in or frequently visit deteriorating housing constructed prior to the 1960s. Children with pica, defined as the ingestion of non-food substances, are also considered to be at high risk.[2]

In addition to the sociodemographic risk factors mentioned above, more frequent screening has been advocated during the summer months when lead poisoning cases are said to be more likely to be diagnosed.[2] Evidence supporting summer screening comes largely from cross-sectional data gathered from large-scale screening programs in Chicago and New York City.[5, 6] Smaller longitudinal studies have reported conflicting results. An early study by Chisolm and Harrison of 32 children with onset of acute lead encephalopathy before two years of age showed that the vast majority of them experienced onset of symptoms during the summer months.[7] Chisolm later reported on 15 children treated for acute lead encephalopathy during one summer whom he followed with blood lead and urinary coproporphyrin tests over the subsequent year.[8] Both tests showed a steady decline, without any evidence of a seasonal effect, and Chisolm concluded that season has little effect upon children not actively ingesting lead. Klein and Schlageter[9] followed 31 children initially screened in the summer with persistently elevated blood lead levels (greater than 40 μg/100ml on three successive determinations) for at least 12 months. They found an overall tendency for blood lead levels to decline from a mean screening level of 51 μg/100 ml to a mean level of about 40 μg 100 ml the following winter, followed by a slight rise to about 44 μg 100 ml the following summer. The Charleston children studied by Reigart and Whitlock[3] were followed over a six-month period from winter to summer and no rise in blood lead level was detected. The authors suggest that

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this may have been due to the smaller average seasonal fluctuations in temperature in Charleston in comparison with the northern cities where the previous studies had been conducted.

The objectives of this study were:

1. To determine whether seasonal fluctuations in blood lead level could be detected in cohorts of children in New York City followed longitudinally. The demonstration of such fluctuations might suggest that a given blood lead level detected during the winter months has a different significance from the same lead level detected during the summer months.

2. To investigate the value of using certain sociodemographic variables and a history of pica to identify those children whose blood lead levels would rise over the ensuing six to 12 months.

Subjects and Methods

This study was carried out in the Brownsville area of Brooklyn, New York, where a lead poisoning screening program is conducted by the Brownsville District of the New York City Health Department (BDHD) as part of the city-wide screening program.[10] At the time the study was conducted, children whose blood lead levels were 55 μg/100 ml and over were designated "cases" and followed with environmental and/or medical intervention.

Initial screening blood lead levels were divided into three groups: low (0 to 34 μg/100 ml), intermediate (35–54 μg/100 ml), and high (55 μg/100 ml and over). Five cohorts of children comprised the study population. Three winter cohorts (A, B, and C with low, intermediate, and high blood lead levels respectively) who were first screened between December 1, 1970 and February 28, 1971 were followed to the summer of 1971. Two summer cohorts (D and E with low and intermediate blood lead levels respectively) who were initially screened in the summer of 1970 were followed to the summer of 1971.*

Screening and follow-up blood lead levels were measured on a 5 ml venous blood sample at the New York City Health Department Laboratories by atomic absorption spectophotometry.**[4] Interviews with the child's parent or guardian, using a standard pre-coded questionnaire, took place at BDHD at the time of the first and second follow-up tests to obtain information on social and demographic variables. Mothers were asked whether their child ever put paper, ashes, or dirt in his mouth, and whether the child had ever handled, mouthed, or ingested pieces of paint and plaster. The mothers were reassured that various mouthing practices were quite normal in young children. Even with this precaution, this part of the history proved one of the most difficult and it was often hard to pin the mother down on details of the history. Comments such as "I've never caught him at it," or "I don't dare leave him alone in case he does it," were not uncommon, and neither was the mother who flatly denied that her child had ever mouthed foreign objects implying that she was too good a mother to let this happen. Because of the lack of reliability of this history it was decided to define the variable "exposure to paint and plaster" to include a history of handling in addition to mouthing or ingesting one or both of these substances. A positive history indicates that exposure to paint or plaster was occurring at the time of the initial screening test.

Results

The ethnic composition of the study population was almost entirely Black (70 per cent) or Spanish-American (29 per cent). Seventy-three per cent of the children came from families on welfare. One-fifth of all mothers had received only an elementary education; only 36 per cent were high school graduates. The age range of the children was from 10 months to 12 years with approximately one-third of the sample 0-2 years of age, one-third 3-4 years of age, and one-third 5 years of age or older. The age distributions of the five cohorts did not differ significantly.

Repeat blood lead test results 6 months after the screen were obtained on 116/211 members of cohorts A, B, and C (55 per cent) and 30/60 members of cohorts D and E (50 per cent). Failure to follow-up members of the cohorts was most marked in the low blood lead cohorts (A and D). This is likely to be due to lack of motivation to return as the parents were informed that the screening result was in the normal range. In addition, the latter families were more likely to have moved away from their address at screening. Further investigation into characteristics of the children not followed, which included contacting a sample of the non-respondents who had not moved, indicated that non-respondents were similar to respondents with regard to age, sex, race, and other demographic characteristics, but tended to be less mobile, having lived in New York City for longer than respondents.

Seasonal Pattern of Blood Lead Levels

Table 1 and Figure 1 contain data on seasonal changes in blood lead levels. The percentage of children in each cohort whose blood lead levels rose over the half-year following screening is greatest in the winter cohorts A and B. A comparison of the percentages with a blood lead level rise in the two low blood lead level cohorts A and D yields a X^2_1 of 13.656 ($p < .01$). A comparison of the same percentages for cohorts B and E yields a X^2_1 of 3.080 ($p > .05$). Analysis of

*Cohort A was a 10 per cent random sample (n = 66) while cohorts B (n = 120) and C (n = 38) were 100 per cent samples. Of the 38 members of cohort C, 13 received chelation therapy during the study period, and only the remaining 25 are included in the results. Cohorts D and E were sampled systematically from BDHD files of children initially screened between July 1 and September 30, 1970 to give a total of 30 in each cohort.

**Study specimens were not specially marked but were sent along with routine screening and follow-up blood specimens. The temporal stability of the blood lead level (which includes laboratory variance) over the range of lead levels encountered in this study is expressed as an intraindividual variance of approximately 25 μg/100 ml (standard deviation of 5 μg/100 ml). Further details on methods of estimation of laboratory and total intraindividual variance may be obtained from the author.

TABLE 1—Blood Lead Level Changes in Children Tested Both in Summer and Winter

Cohort	n	Percentage with Increase in Blood Lead Level	Mean Winter Blood Lead Level (μg/100ml)	Mean Summer Blood Lead Level (μg/100ml)	Mean Change in Blood Lead Level (μg/100ml)	95 Per Cent Confidence Interval (μg/100ml)
			Winter Cohorts (Winter to Summer Transition)			
A	32	75	24.5	29.9	+ 5.4	$2.0 < \mu < 8.8$
B	70	39	41.5	39.3	− 2.2	$-4.7 < \mu < 0.3$
C*	14	0	58.7	46.1	− 12.6	$-17.6 < \mu < -7.6$
			Summer Cohorts (Summer to Winter Transition)			
D	10	10	27.1	23.5	− 3.6	$-7.8 < \mu < 0.6$
E	20	15	41.2	33.9	− 7.3	$-11.4 < \mu < -3.2$

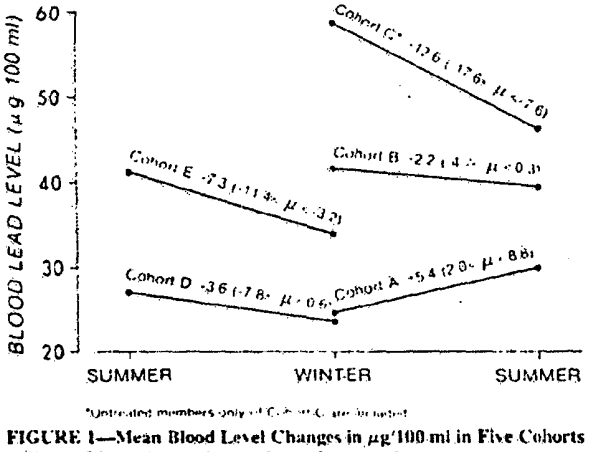
*Untreated members of cohort C only

mean blood lead level changes by cohort indicates a statistically significant rise for cohort A and a fall for cohorts C and E ($p < .05$).

Exclusion from the analysis of children aged five and over (approximately one-third of the sample) did not affect the mean direction of blood lead level change by cohort but did affect the size of the change by increasing a mean rise or lessening a mean fall in blood lead level.

Subsets of cohorts D and E were retested the following summer: their mean winter and summer blood lead levels were as follows:

	n	*mean winter blood lead level* (μg/100 ml)	*mean summer blood lead level* (μg/100 ml)
cohort D	8	24.0	24.8
cohort E	14	33.9	35.1



*Untreated members only of Cohort C are included

FIGURE 1—Mean Blood Level Changes in μg/100 ml in Five Cohorts (95% confidence intervals are shown in parentheses).

Although the numbers are small, and the changes not statistically significant, cohorts D and E did show small fluctuations in the expected directions.

When children with a history of paint or plaster exposure were excluded from the analysis there was no significant change in the blood lead level patterns already described. It therefore seemed unlikely that a seasonal pattern was being obscured by children currently ingesting lead or whose lead levels had been elevated previously. The possible effects of various interventions including Public Health Nurse home visits, Sanitarian home visits and inspections, environmental intervention (home repair), and study interviews were examined in a similar way, but the exclusion of children in whom these interventions had been applied did not significantly alter the direction of previously described blood lead level changes.

Statistical regression to the mean seemed to be the predominant determinant of blood lead level change. Analysis by 10 μg/100 ml groupings demonstrated regression to the 35–44 μg/100 ml range; children with screening levels below this range showed a mean increase and those with screening levels above this range showed a mean decrease, regardless of season of testing.

Prediction of Blood Lead Level Change

At the time of screening, 70 per cent of the children were living in or frequently visited housing described by the parent or guardian as poor, i.e., old with peeling paint and/or broken plaster (no home visits were made to confirm this verbal report). A further 16 per cent had previously lived in poor housing. A significantly larger percentage of cohort C (high blood lead levels) currently or previously lived in poor housing (94 per cent) in comparison with cohort B (88 per cent) and cohort A (72 per cent).

The prevalence of mouthing of foreign substances in the total sample (in whom the history was known) was 34 per cent for paper, 12 per cent for ashes, and 4 per cent for dirt while 17 per cent were exposed to paint or plaster. More than one of the above characteristics was reported in 39 per cent of the children. Not surprisingly, exposure to paint or

plaster was found only in children living in poor housing. It was interesting that mouthing of other substances (paper, dirt, ashes) was also more common in this group, being reported in 39 per cent of those living in poor housing as compared to 17 per cent of children living in good housing. This relationship held even after age-adjustment.

To examine the role of various sociodemographic variables in predicting blood lead level change, those children first screened in the winter but not designated cases were examined (cohorts A and B). (Three members of cohort B were excluded because they were not interviewed, leaving 67 children in cohort B and 32 children in cohort A.) Of these 99 children, 14 had blood lead levels which rose 10 μg/100 ml or more by the following summer: seven from cohort A and seven from cohort B.* Only two of the sociodemographic and pica variables used in the study showed any clear and consistent relationship to blood lead level change: age under three at screening, and a history of exposure to paint or plaster. Table 2 shows the sensitivity and specificity of using these variables alone or in combination to identify those children whose blood lead levels rose 10 μg/100 ml or more by the following summer.

Discussion

In discussing the results of this study, it is first appropriate to consider the extent to which the results may be generalized. The reference population for this study was the population of children screened for lead poisoning in the Brownsville district of New York City. This population was in many ways typical of one at "high-risk" for lead poisoning, being an urban ghetto population of Black and Spanish-American children of predominantly welfare families, living in deteriorating housing with all its attendant problems. Although the non-response rate was high, non-respondents appeared to differ from respondents only in mobility which was not found to be related to blood lead level changes. It therefore seems unlikely that selection bias could account for the results of this study. The sample, however, is a small one.

Although subtle evidence was found of a seasonal pattern of blood lead levels, season did not exert as great an effect as had appeared from a review of the literature. Data from the Chicago[5] and New York City[6] lead poisoning screening programs indicated a clear seasonal pattern in the percentage of high blood lead levels detected, with a minimum in the winter and a maximum in the summer. The difference between mean winter and summer blood lead levels in the Chicago study was 15 μg/100 ml. These data were cross-sectional rather than longitudinal and it is possible that factors such as increased screening of high-risk areas during the summer months might account in part for the results.

The usual explanation for the summer increase in blood lead level is increased lead absorption due to vitamin D as a response to increased exposure to sunlight.[11, 12] More recent work by Sorrell and associates[13] suggests that, regardless of blood lead level and season, serum 25-(OH)D (the most reliable indicator of an individual's vitamin D status) is primarily a function of vitamin D intake and that high blood levels tend to be associated with a relative vitamin D deficiency, rather than an excess. The relationship between lead and vitamin D is clearly complex and may also involve interference with the biogenesis of the hormonal form of the vitamin (1, 25-$(OH)_2$) from 25-(OH)D.** Another explanation for a seasonal increase in blood lead levels is increased ingestion and/or inhalation of dust-borne lead during the summer months.[14]

In this study, the hypothesized seasonal effects, if indeed they exist, appear to be of lesser importance than the phenomenon of regression to the mean.[15] The roles of various types of intervention (medical, environmental, and interview effect) in causing this decline in blood lead level were evaluated, and no evidence for a relationship was found (although sample sizes were small). There was also no suggestion that the seasonal pattern might have been obscured by

TABLE 2—Age* and Pica‡ as Predictors of Blood Lead Level Change**

Predictor	Rise ≥ 10 μgm/100ml (n = 14) with Predictor (a)	Rise ≥ 10 μgm/100ml (n = 14) without Predictor (b)	No Rise (n = 85) with Predictor (c)	No Rise (n = 85) without Predictor (d)	Per Cent Sensitivity $\left(\frac{a}{a+b}\right)$	Per Cent Specificity $\left(\frac{d}{c+d}\right)$
Age < 3	8	6	12	73	57	86
Pica	10	4	19	66	71	78
Age < 3 or pica***	13	1	26	59	93	69

*Age at screening
‡History of handling, mouthing, or ingesting paint or plaster at time of screening
**Data from all members of cohorts A and B as listed in Table 1, except three children whose pica history was unknown
***χ^2_1 = 19.570, $p < .001$

**The cut-off of 10 μg/100 ml rise in blood lead level was chosen as being twice the standard deviation for intraindividual variation.

**Rosen J: Personal communication to the author.

the presence of children who were either currently ingesting lead or who had previously suffered high blood lead levels.

Two other explanations should be considered: the overall decline in blood lead level could have been caused by the educational effects of the screening process itself, or there could have been an inconsistency over time in the laboratory analyses. A change in the laboratory analytic results over the period of the study seems an unlikely explanation as standard specimens were used daily as reliability checks. The educational effect was a factor shared by all study members and it could have produced the observed effects by causing an acceleration in the normal aging process whereby a child stops mouthing foreign objects.

The variables which were found to be of major importance in predicting subsequent blood lead level change were the child's age at screening and a history of exposure to paint or plaster. Other authors have described the important relationship of age to increased lead absorption[6, 10] and so it was not surprising that age turned out to be an important variable in predicting subsequent blood lead level change: children under age three were at greatest risk of showing an increase in blood lead level over the six months following screening. It was surprising, however, that there was not a greater correlation of age with actual blood lead level; the mean and range of age at screening were very similar in each of the cohorts. Furthermore, a recent history of exposure to paint or plaster was present to the same extent in both the older and younger members of cohort C. Although the numbers involved are rather small, it appears that children over three years old are more likely to have high blood lead levels than had previously been thought.

A history of pica for paint for plaster has been used as a screening device in New York City in the past[17] but has largely been abandoned as too unreliable and of low sensitivity. The results from the present study suggest that about one-third of the children with high blood lead levels (Cohort C) would have been missed if a history of exposure to paint for plaster (recent or past) had been used alone as a screening test.

The results of this study suggest that selective follow-up of children whose screening blood lead levels are in the low to intermediate range (<55 μg 100 ml) and who at screening are either under age three or whose parents respond affirmatively to the question, "Does your child ever handle pieces of paint or plaster or put them in his mouth?", may be a sensitive and fairly specific means of identifying those children whose blood lead levels will rise over the ensuing months. This approach could be tested in a variety of screening programs to determine its value.

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