Prevalence of Excess Lead Absorption and Associated Risk Factors in Children Enrolled in a Midwestern Health Maintenance Organization

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ABSTRACT. *Objective.* **To assess the prevalence of lead intoxication in children in a defined low-risk population at the new levels recommended by the Centers for Disease Control and Prevention.**

Design. **During an 11-month period, whole blood lead tests were performed on 4678 children at routine well-child visits at 9 months and 2 years of age. For the last 8 months of the study, parents were asked to complete a prescreening risk factor questionnaire at these visits. The questionnaire and blood lead results were then matched. Data were collected from October 1, 1991 through August 31, 1992.**

Setting. **The study subjects were all enrolled in Group Health, Inc, a large health maintenance organization. Its 17 staff model clinics serve urban and suburban populations in the Minneapolis-St. Paul area. More than 95% of the population had coverage based on employment, not Medicaid.**

Results. **Results indicated that 2.5% (n = 119) of the children had BPb levels ≥10 μg/dL. Urban clinics had rates of elevated BPb levels three to eight times those of suburban clinics ($P < .00001$), but the number of elevated BPb levels at the suburban clinics was greater than expected. BPb levels were significantly higher in summer and fall ($P < .00001$). The prescreening questionnaire addressed five areas potentially associated with risk according to the literature: housing, siblings with lead poisoning, parental hobbies or work involving lead, proximity to highways, and use of cultural medicines. Positive correlations were found between elevated BPb levels and residences built before 1950 ($P < .00001$). For children living in housing built before 1950, positive correlations were found between elevated blood lead levels and peeling paint ($P < .01$) or remodeling ($P < .0001$).**

Conclusions. **Children who are at low socioeconomic risk but who live in housing built before 1950 are at increased risk for lead poisoning. The risk is greater if the house has peeling paint and especially if there is recent or ongoing renovation. Recommendations based on these results and the Centers for Disease Control and Prevention guidelines are made for screening programs in similar populations, and for the need to increase community awareness concerning this issue.** *Pediatrics* **1994;93:172–177;** ***lead poisoning prevalence, risk factors.***

ABBREVIATIONS. BPb, whole blood lead; CDC, Centers for Disease Control and Prevention; GHI, Group Health, Inc; HMO, health maintenance organization.

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Excess lead absorption in the early years of life causes decreased cognitive intellectual function that persists into late adolescence.[1–3] It also causes poorer scores on many measures of motor developmental status.[4] The first 2 years of life seem to be a time of increased sensitivity to the adverse affects of lead on the central nervous system. The time of maximal sensitivity appears to be around 2 years of age. A recent Yugoslavian study[5] examined both iron and lead status, separating these two factors. Results indicated that lack of iron may both exacerbate effects of excess lead and independently adversely affect intellectual function.

Periodically the Centers for Disease Control and Prevention (CDC) publishes guidelines for management of lead poisoning. The 1985 guidelines[6] considered children to be lead poisoned only if the whole blood lead (BPb) was ≥25 μg/dL and the free erythrocyte protoporphyrin was ≥35 μg/dL. With these guidelines, populations of inner-city children with low socioeconomic status were considered to be the primary group at risk for lead poisoning. Confirming this, a previous study conducted on this low-risk population found that only 2 of almost 5000 children met the definition of lead poisoning.[7]

In 1991, the CDC published a new set of guidelines.[8] These have dramatically lowered the levels at which children are considered at risk for lead toxicity. The new guidelines consider any BPb ≥10 μg/dL to be of concern.

These new guidelines suggest near universal screening of both high- and low-risk children, and a multitiered response to elevated blood lead levels. For children with a level <10 μg/dL, no intervention is required. For those with levels of 10 μg/dL through 14 μg/dL, monitoring of BPb levels is recommended, and community-based public health action is recommended if the community has large numbers of children in this category. For those with levels of 15 μg/dL through 19 μg/dL, it is recommended that they be monitored with frequent blood lead tests. They should also be reported to public health authorities for parental education, environmental investigation, and, if levels persist, clean-up of the child's environment. For those with levels of 20 μg/dL or greater, the recommendations include reporting, environmental intervention, and full medical examination and treatment if indicated by the evaluation. Levels >45 μg/dL or symptoms or signs of lead intoxication constitute a medical emergency.

In light of these new CDC guidelines and the studies cited, the epidemiology of excess lead absorption

must be reexamined. Little is known about the prevalence at these lower levels across populations and the impact of various risk factors.

The current study was designed to determine the prevalence and risk factors for excess lead absorption in children considered as low-risk. This study measured blood lead levels in >4000 children younger than age 3 years in a large health maintenance organization (HMO) population. This study also attempted to determine risk factors associated with elevated blood levels through the use of a prescreening questionnaire. By identifying children at risk it might be possible to decrease the number of blood samples needed to assure safety for such a population.

METHODS

Study Population

The study population consisted of children younger than age 3 from Group Health, Inc, a large HMO in the metropolitan area of Minneapolis and St. Paul. The HMO (approximately 300 000 members) serves both urban and suburban populations. Almost all the members of the HMO receive their coverage through their employer. Thus, the defining demographic characteristic of this population is that at least one member of the family is employed at a job that offers health care insurance. This effectively eliminates the lowest 20% of socioeconomic strata, resulting in a study population traditionally considered at low risk and eliminating those generally considered at highest risk for lead poisoning. The 17 HMO clinics are located throughout the seven-county metropolitan area, six in urban locations and eleven in suburban locations. The metropolitan area has a population of about two million. Most of the housing units in the central cities were built before 1950, whereas much of the housing in the first ring suburbs was built between 1950 and 1970. Many but not all the homes in the second and third ring suburbs were built more recently. Heavy traffic corridors exist throughout the area.

Lead Testing

From October 1, 1991 through August 31, 1992, the protocol called for all children aged 9 months and 2 years to be tested at their well-child visits to determine their BPb levels. Some children less than 3 years of age were tested at appointments other than at 9 months or 2 years. These data are included in the analysis. The protocol called for confirmation of all fingerstick values ≥15 μg/dL by venipuncture. The venipuncture value was used for study purposes. If more than one fingerstick was performed and there was no confirmation by venipuncture, the first value obtained was used. All tests were conducted at the HMO central laboratory by aniodic stripping on an AVIV analyzer. The laboratory successfully participates in the CDC proficiency program. All values reported as "<5 μg/dL" (the lower limit of reliability for our equipment) were assigned a value of 2.0 μg/dL for purposes of analysis.

Prescreening Questionnaire

The prescreening questionnaire was designed to examine risk factors which had been reported in the literature (see Appendix). Beginning on January 1, 1992, the questionnaire was given to the parents of all children less than 3 years of age at all well-child visits. Any positive answers to the questionnaire triggered a whole blood lead test, regardless of the child's age. In the occasional instances in which the blood was not drawn on the same day the questionnaire was completed, matches were made if the blood was drawn within 6 months of questionnaire administration.

Data Analysis

Analysis related only to BPb values was conducted on blood drawn from October 1, 1991 through August 31, 1992. Analysis that considered the relationships between questionnaire data and BPb values was performed on blood samples obtained between January 1, 1992 and August 31, 1992, when the questionnaire was in use. Associations between BPb levels and various risk factors were assessed using Pearson's χ^2 test of significance.

RESULTS

Whole Blood Lead Results

Of approximately 5500 eligible children, 4678 children (85%) had their whole blood lead tested. Even in this population, traditionally considered at low risk, 2.5% had levels equal to or greater than the CDC threshold of 10 μg/dL (Table).

Elevated BPb rates from urban clinics were compared with those in suburban clinics. The results are also shown in the Table. As was expected, the rates at the urban clinics were from 2.4 to 8 times higher than those of the suburban clinics for all three levels ($P < .0001$). The number of children with elevated BPb levels at the suburban clinics was greater than expected.

BPb levels varied significantly by season ($P < .0001$). Because 5 μg/dL is the lower limit of reliability for our equipment, all values reported as "<5 μg/dL" were assigned a value of 2.0 μg/dL for this analysis. The mean values in summer (3.50 μg/dL) and fall (3.28 μg/dL) were substantially greater than those in winter (2.50 μg/dL) and spring (2.61 μg/dL). Examining the data on a monthly basis (Fig 1) in October 1991, July 1992, and August 1992 the mean BPb values are substantially higher. No data were collected for the month of September.

Examining age-specific data, the mean BPb level for children less than 12 months of age was 2.69 μg/dL. For children older than 18 months of age, the value was 2.96 μg/dL. In this population, older children had higher BPb levels ($P = .0018$).

Relationship of Questionnaires and Whole Blood Lead Values

Questionnaires were completed and matched to BPb values for 2440 children. This represents a 65% response rate. Fewer than 2% of the families actually refused. The remaining missing responses were due to the challenges of sustained data collection from multiple sites without on-site research personnel. Based on potential risk factors suggested by the literature, questions covered the following five categories: housing, siblings with lead poisoning, parental lead related hobbies and work, proximity to highways, and cultural medicines. Four additional questions relating to iron deficiency are not addressed in this paper.

A strong association existed between elevated BPb levels and residence in a dwelling build before 1950 (Fig 2). Forty-three percent of children with BPb levels <10 μg/dL lived in housing built before 1950 in contrast to 100% of those with BPb levels of 20 μg/dL or greater.

TABLE. Percentage of Urban and Suburban Children by Blood Lead Level

Blood Lead Value, μg/dL	Urban* (n = 1838)	Suburban* (n = 2840)	Combined* (n = 4678)
<10	95.6	98.6	97.4
10–14	02.6	01.1	01.6
15–19	00.7	00.2	00.4
>19	01.1	00.1	00.5

* Values stated are percentages.

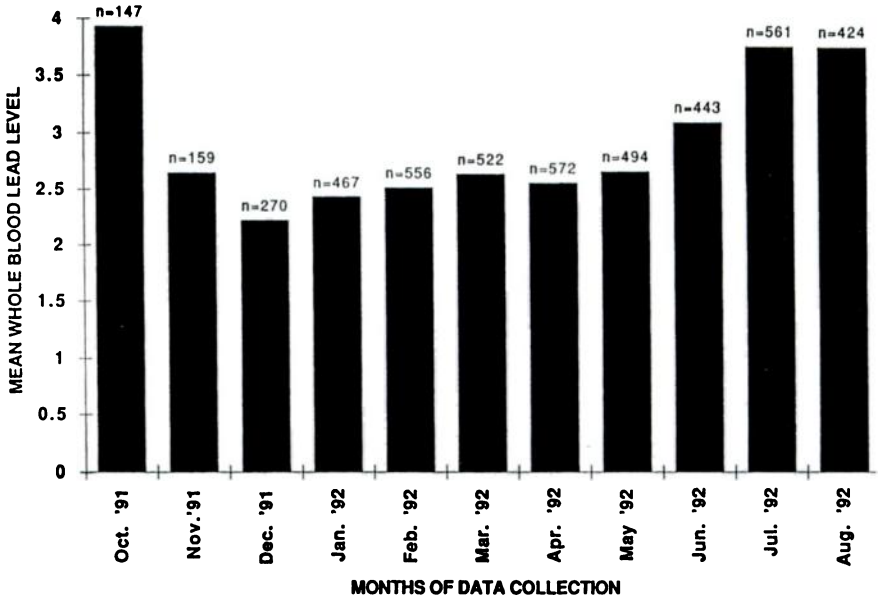

Fig 1. Monthly variation of mean whole blood lead values (n = 4615).

For children living in housing built before 1950 (n = 1054), questions were asked about exposure to peeling paint and to recent or ongoing renovation. Both exposures were associated with elevated BPb levels (Figs 3 and 4). The strongest association found was with recent or ongoing renovation. Forty percent of children with BPb levels <10 μg/dL answered "yes" to the question about recent or ongoing renovation, compared with 82% of children with levels of ≥20 μg/dL.

No association between living within one block of a highway and elevated BPb levels was found (P = .85). The number of people answering "yes" to the other questions was too small for statistical analysis.

Predictive values were also calculated at various levels of BPb elevations for both the questionnaire as a whole and for the single most useful question, whether the housing was built before 1950 (question 1). For the questionnaire as a whole at cutoffs of 10, 15, and 20 μg/dL, the sensitivity was 75%, 81%, and 89%. Specificity at all three levels was 49%. For question 1, at cutoffs of 10, 15, and 20 μg/dL, the sensitivity was 69%, 73%, and 79%. Specificity at all three levels was 57%. Negative predictive values (the probability that a child who tests negative does not have excess lead absorption) were very high, ranging from 98.1% to 99.8% for the questionnaire as a whole and from 98.0% to 99.6% for question 1.

DISCUSSION

This study has demonstrated excess lead absorption in 2.5% or 119 children of 4678 in an HMO population in the Minneapolis-St. Paul metropolitan area using the new CDC guidelines. This is a population that would be expected to have a very low rate of excess lead absorption. When this same population was studied 5 years ago by Stang and Nordin,[7] using the 1985 CDC guidelines of a free erythrocyte proto-

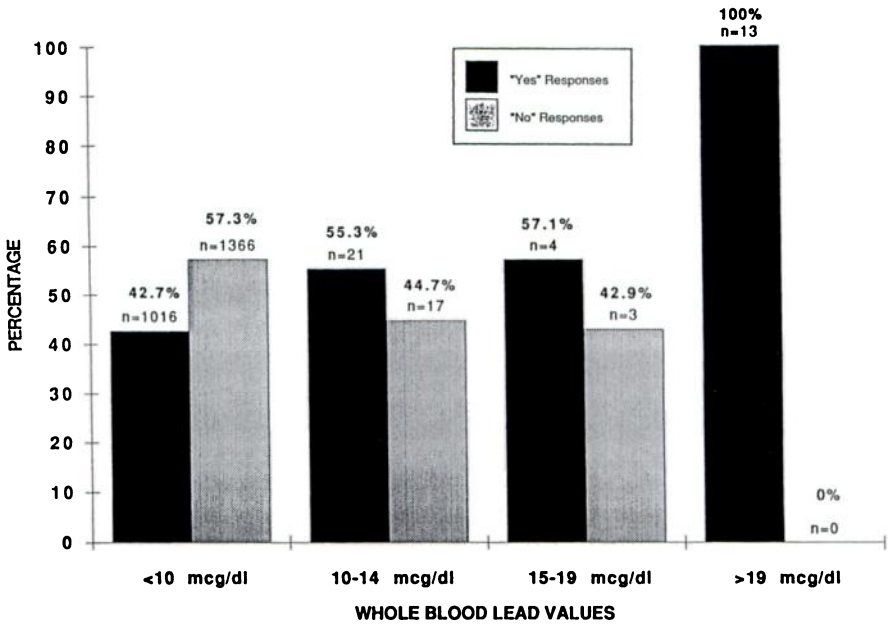

Fig 2. Percentage of responses to "living in housing built before 1950" by whole blood lead level (n = 2440, P < .00002, df = 1).

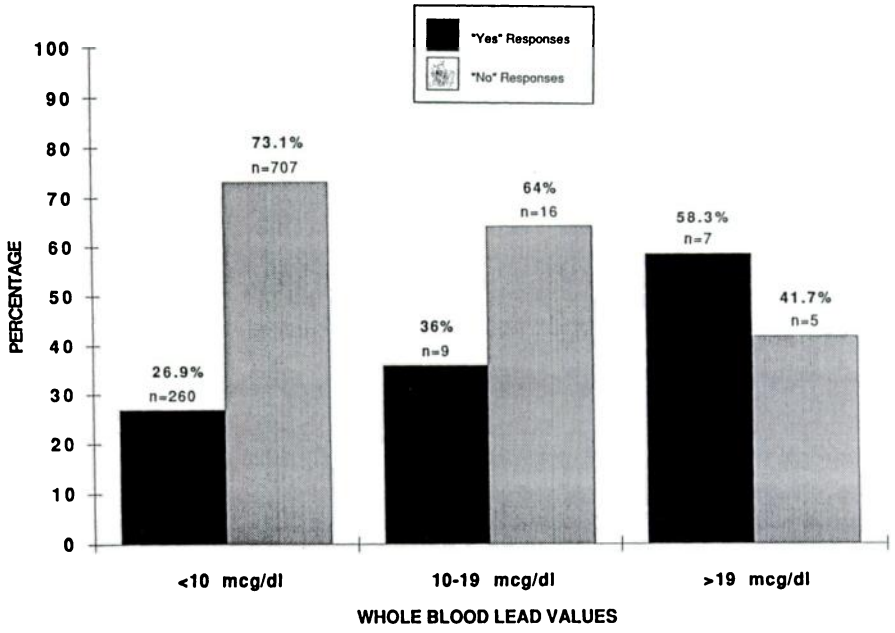

Fig 3. Percentage of responses to "living in housing built before 1950 that has peeling paint" by whole blood lead level (n = 1004, $P < .01$, $df = 1$).

porphyrin of ≥35 μg/dL and a BPb of ≥25 μg/dL, only two children were classified as lead-toxic of almost 5000 children screened. Thus, the new CDC guidelines have expanded the problem of excess lead absorption beyond the ghettos into middle America. Excess lead absorption is a greater problem in the central cities than in the suburbs. Although the percentage of children at the suburban clinics with excess lead absorption was small (1.4%), in absolute numbers in a large practice this is a disturbing figure, and much greater than the prevalence of diseases such as phenylketonuria or maple syrup urine disease for which we are already screening. The reduction in morbidity to our children from a properly conducted lead screening program would be greater than that recently seen with effective vaccines against *Haemophilus influenzae* (Minnesota Department of Health, personal communication, 1992).

This study matched 2440 questionnaires with blood samples. This represents 51% of all bloods collected and 65% of bloods collected once questionnaires were initiated. Very few families refused the questionnaire. Coordinating the administration and collection of these questionnaires from multiple clinics presented ongoing logistical challenges. There was no systematic pattern to the missing data, thus the 65% should be representative of the population. A more likely source of bias is seasonal, the lack of questionnaire data from the fall. No questionnaire data were available to match to blood levels obtained October through December. It is unlikely that these children differed from the rest of the population, but it is a potential source of bias.

In this population, the risk factors for excess lead absorption included the following:

1. Housing built before 1950
2. The presence of recent or ongoing renovation in pre-1950 housing.
3. The presence of peeling paint in pre-1950 housing

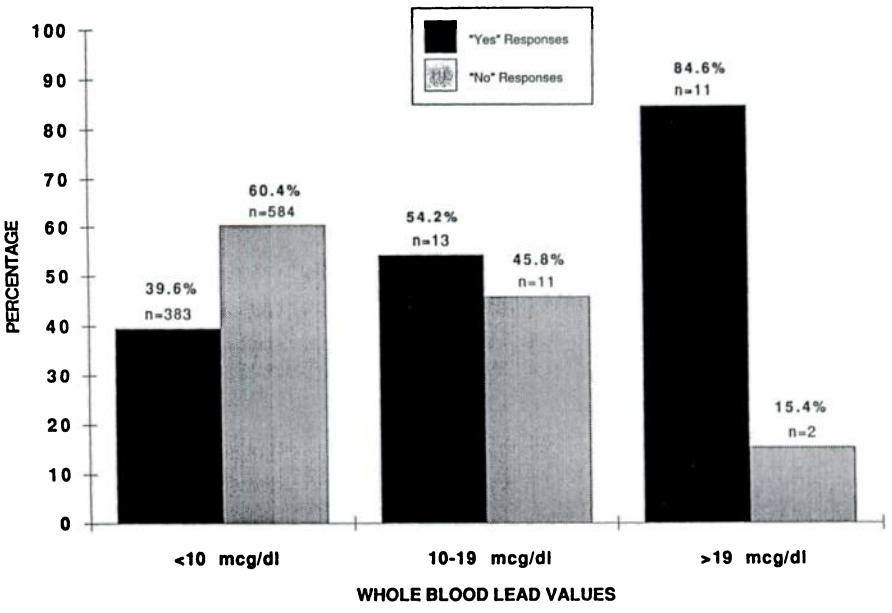

Fig 4. Percentage of responses to "living in housing built before 1950 that has ongoing or recent renovation or remodeling" by whole blood lead level (n =1004, $P < .0005$, $df = 1$).

4. Urban residence
5. Summer and fall seasons.

All the parents of children in our population with BPb levels ≥20 μg/dL reported living in housing built before 1950. Eighty-two percent of these also reported that the housing was undergoing or had recently undergone renovation. Although case reports of this have been published,[9] this has not been previously demonstrated in a large study. Forty percent of the children who were not lead-toxic had renovation going on in their homes as well. Thus, not everyone reporting renovation was poisoned. Those with BPb levels >20 were twice as likely (58% vs 27%) to report peeling paint as families of nontoxic children. Exposure to renovation or peeling paint significantly increases the risk of lead poisoning. Further study is warranted to discern what critical elements of renovation are most dangerous.

Within this population, asking the single question as to the age of housing had a sensitivity of 79% and a negative predictive value of 99.6% for BPb levels ≥20 μg/dL. The questionnaire as a whole had a sensitivity of 89% and a negative predictive value of 99.8% for the same cutoff. Thus, the single question about housing age was a good identifier of children in this population at highest risk, and with a cutoff of 20 μg/dL, only 6 of 3142 children whose parents answered the questionnaire would have been missed.

The seasonal variation could be due to either a greater amount of exposed contaminated soil or to more open windows and more exposure to paint in window wells during the summer and early fall months. This pattern may be different in different climates.

A question asking whether the family lived within one block of a highway was not found to be significant in this study. The numbers were inadequate for the other questions to determine their predictive value. Thus it is not possible to say with these data whether the other questions on the questionnaire are effective in prescreening for other known risk factors. (There is some concern among workers in the field that families using folk medicines will be reluctant to admit to doing so on a questionnaire.)

Based on these data and the current CDC guidelines, we recommend the following measures should be implemented for *similar populations* of children:

1. The test of choice for excess lead absorption is the whole blood lead.
2. All children living in urban areas should be screened at least twice in the early years, at approximately 9 months to 1 year of age and at approximately 2 years of age.
3. All children living in suburban homes built before 1950 should be screened on a schedule similar to the urban children.
4. All children living in pre-1950 housing which is being renovated should have their blood lead tested immediately, and work delayed until safety is assured.
5. For children with elevated BPb levels, treatment and follow-up should be done according to CDC protocol.

The data presented in this study come from an HMO population in a northern midwestern city. Although further studies are currently underway expanding beyond the HMO to incorporate a more representative population from the Twin Cities area, comparable data are needed from other areas and other populations. The demographics of lead poisoning are likely to vary markedly across geographic areas and in children living in poverty.

If these data are confirmed by additional broadly based studies, major changes in housing renovation methods and codes will be needed, and the public will need to be more fully educated about this hazard.

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APPENDIX

GROUP HEALTH, INC.

PRESCREENING QUESTIONNAIRE

IRON DEFICIENCY AND LEAD TOXICITY

Label

Circle the answers that are correct for your child.

1. Does your child live in or visit a house built before 1950 (now or in the last 6 months)? 1. yes no
   If so:
   A. Is there any peeling paint? 1A. yes no
   B. Is there any planned or ongoing renovation or remodeling? 1B. yes no

2 Does your child have a brother, sister, housemate or playmate with confirmed lead poisoning? 2. yes no

3. Is there an adult in the household who works with lead in either a job or hobby (for example: smelting, batteries, soldering, print shop, autobody repair)? 3. yes no

4. Do you live near a lead smelter or battery recycling plant, or other industry likely to release lead? 4. yes no

5. Do you live within 1 block of a major highway? 5. yes no

6. Does your child receive foreign or cultural medicines (azarcon, greta, pay looah, shung fa) 6. yes no

7. Have you been told your child has low iron? 7. yes no

8. If your child is less than one year old, is he or she drinking mostly low iron formula, cow's milk and juice? 8. yes no

9. Is your child drinking more than 24 ounces of milk (not formula) per day? 9. yes no

10. Did your child weigh less than 6 pounds at birth? 10. yes no

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By signing your name below, you allow the information on this questionnaire to be entered in a data base which will be used by GHI researchers to couple it with the results of the lead and iron screening test done today. This data will be used to find out how effective this questionnaire actually is in finding children who have low iron or excess lead in their bodies. This data will not be released any further without your additional written consent. By not signing you do not negatively affect your child's care in any way.

Signature _____ Date_____

Relationship to patient _____

Address _____
(2-92)