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Lead Levels in High-risk and Low-risk Young Children in the Minneapolis-St Paul Metropolitan Area

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ABSTRACT. *Objectives.* To determine distribution of lead levels among children in a low-risk area; to validate a prescreening questionnaire; and to determine if universal lead screening is necessary in children in this area.

Design. Blood lead levels and questionnaires were obtained on eligible patients. Data were analyzed using stepwise regression analysis.

Setting. Community clinics and a health maintenance organization (HMO) in the Minneapolis-St Paul metropolitan area.

Patients. A total of 9603 children at well-child visits, age 6 months to 6 years at community clinics, and 6 months to 3 years at the HMO.

Outcome Measures. Whole blood lead levels (WBLs) and questionnaires.

Results. The total sample rate of WBLs at ≥ 10 $\mu\text{g}/\text{dL}$ was 12%, at ≥ 15 $\mu\text{g}/\text{dL}$ was 3½%, and at ≥ 20 $\mu\text{g}/\text{dL}$ was 1.2%. At both 10 $\mu\text{g}/\text{dL}$ and 15 $\mu\text{g}/\text{dL}$, the non-HMO group was at higher risk. For both groups, risk factors included living in the central cities, and living in housing built before 1950. For the non-HMO group a history of the child eating paint chips, or the child or a sibling having previous lead poisoning were also risk factors.

Conclusions. Not all children need lead screening. Children living in the central cities, or with the risk factors of living in housing built before 1950 or a previous history of lead poisoning should be screened. *Pediatrics* 1998;101:72-76; *lead poisoning prevalence, children, screening, risk assessment questionnaires.*

ABBREVIATIONS. CDC, Centers for Disease Control and Prevention; WBL, whole blood lead; NHANES, National Health and Nutrition Examination Surveys; HMO, health maintenance organization.

In 1991 the Centers for Disease Control and Prevention (CDC) published a revised statement on lead poisoning in children, which moved the whole blood lead (WBL) level of concern from 25 $\mu\text{g}/\text{dL}$ to 10 $\mu\text{g}/\text{dL}$.¹ Because the epidemiology of WBLs at lower levels was unknown, the CDC recommended that all children be screened. If a large number of children were tested in a population and

found not to have WBLs ≥ 10 $\mu\text{g}/\text{dL}$, then screening in that population could be discontinued.

Between 1978 and 1990, average blood lead levels declined markedly. The National Health and Nutrition Examination Surveys (NHANES) II data from the late 1970s showed an average WBL of 12.9 $\mu\text{g}/\text{dL}$. Data from phase one of NHANES III, collected between 1988 and 1991, showed the average WBL to be 2.9 $\mu\text{g}/\text{dL}$.^{2,3} This difference is presumed to be due mostly to the elimination of lead aerosols from automobile exhaust.

However, data from NHANES III show that a sizable number of children still have WBLs ≥ 10 $\mu\text{g}/\text{dL}$. Children at highest risk of having excess lead burden are children of color in low-income families living in central cities in large urban areas.

The current study assessed the epidemiology of elevated blood lead levels in the metropolitan area of Minneapolis-St Paul. The goals were:

1. To determine the prevalence of elevated WBLs among low- and high-risk children in the Minneapolis-St Paul metropolitan area,
2. To validate a prescreening risk assessment questionnaire, and
3. To determine whether universal screening of children for lead poisoning is necessary in this area.

This article presents the WBL results and associated risk factors. Risk assessment included both demographic data and data from prescreening questionnaires.

METHODS

Study Sample

A nonrandom sample from the metropolitan area of Minneapolis and St Paul was studied. Subjects were identified by the site of medical care. About 30% of the total sample were from the 17 clinics of a large health maintenance organization (HMO). The other 70% were from 16 community-based sites including health departments, community clinics, Women, Infants, and Children clinics, and hospital primary care clinics.

The HMO subjects provided wide geographic coverage of the 7-county metropolitan area. Almost all the children in the HMO had private health insurance and represent the low-risk portion of the population.

The community-based clinics provided subjects expected to be at high risk, using factors enumerated in NHANES III. Although the entire metropolitan area was not included in this portion of the sample, there were sites from the central city, suburbs, and exurbs. See Fig 1 for the geographic distribution of the entire study sample.

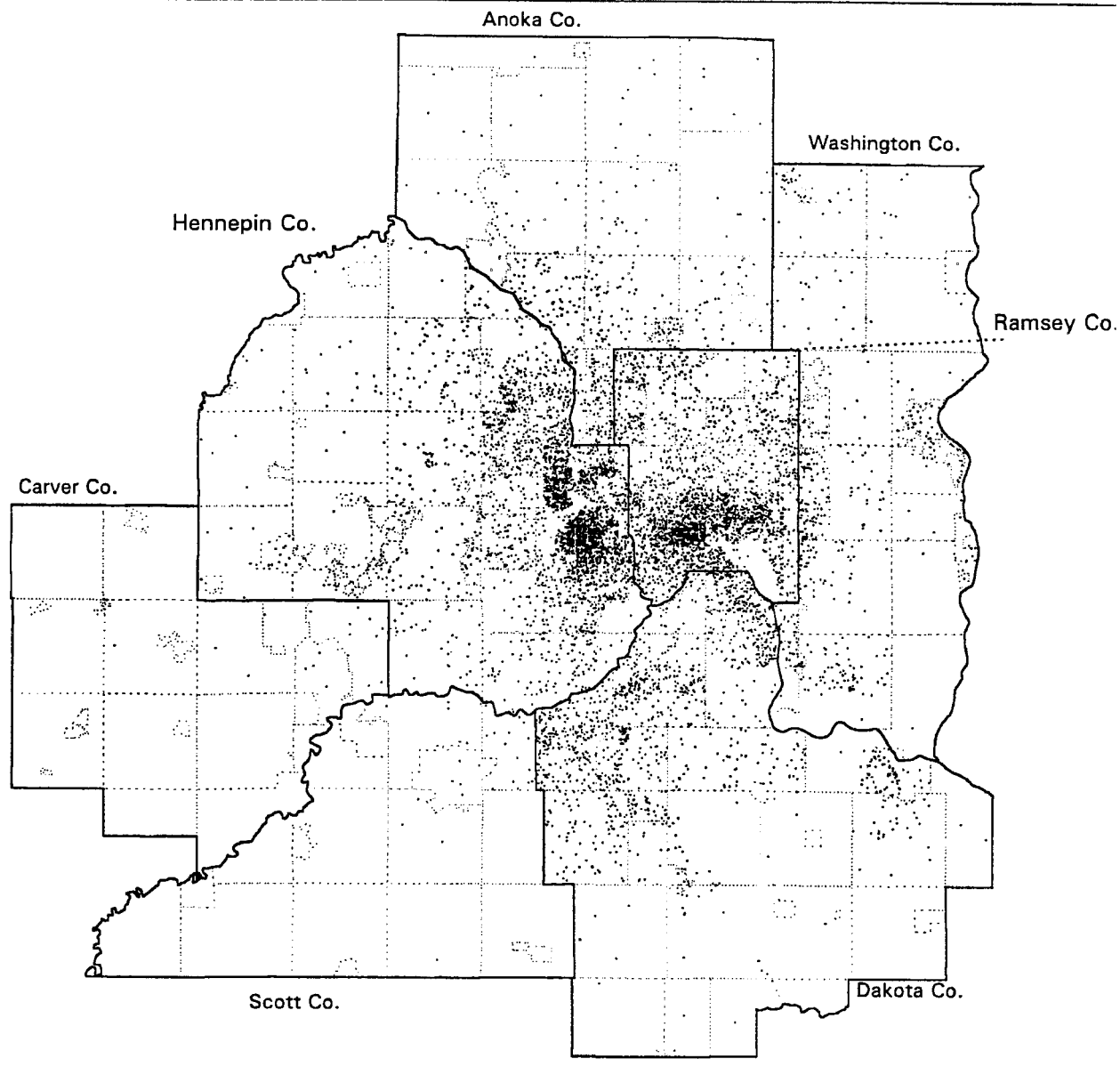
To assess the differences between the study sample and the 7-county metropolitan area, census data from 1990 were obtained. These census data define the reference population. Table 1 com-

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NOTE: Aggregated by Census Tract
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Fig 1. Twin cities' lead study. All participants (N = 9603).

compares the demographics of the HMO population, the community-based clinic (non-HMO) population, and the whole study population with the reference population. The HMO population was similar to the reference population. The non-HMO population was less likely to be white, more likely to live in poverty census tracts, less likely to live in post-1950 housing, and more likely to rent. Thus, the HMO population had a lower level of exposure for all four traditional risk factors ($P < .0001$ for all factors).

Research Design

The study was conducted for 1 year, from September 1, 1992 through August 31, 1993. An attempt was made to enroll all children who presented for well-child visits from 6 months to 6 years of age in the non-HMO subsample and from 6 months to 3 years of age in the HMO subsample. A blood sample was obtained and a risk assessment questionnaire was completed by the parent. In 9603 cases, questionnaires, blood samples, and informed con-

sent were matched, and these are the data on which the analysis is based.

Most blood samples were collected by fingerstick using a standardized technique, and some by venipuncture. Two of the non-HMO sites did all testing by venipuncture. The protocol called for all fingersticks with a WBL $\geq 15 \mu\text{g}/\text{dL}$ to be confirmed by venipuncture. This was not consistently done. WBL testing was performed at seven laboratories, all of which participate in the CDC proficiency program.

The same questionnaire was used at all sites. It was translated into Spanish, Hmong, Laotian, Vietnamese, and Russian. Data from all completed questionnaires were entered twice to verify accuracy.

χ^2 was used for the univariate analysis. Stepwise logistic regression was used for further analysis. Information was analyzed using a cutoff of both $10 \mu\text{g}/\text{dL}$ and $15 \mu\text{g}/\text{dL}$. At $10 \mu\text{g}/\text{dL}$ the data were analyzed as HMO only, non-HMO, and total sample. At $15 \mu\text{g}/\text{dL}$ the data were analyzed as non-HMO and total sample.

TABLE 1. Characteristics of Children Age 6 Months to 6 Years in the Entire Study Group, HMO, Non-HMO, and a Reference Population

| | 1990 Census | Entire Study Population | HMO Population | Non-HMO Population |
|------------------------------------|-------------|-------------------------|----------------|--------------------|
| Race | | | | |
| White | 84% | 55% | 83% | 43% |
| Live in a 20% poverty census tract | 14% | 28% | 7% | 37% |
| Living in housing built after 1950 | 71% | 46% | 62% | 39% |
| Rent home | 27% | 56% | 20% | 72% |

The numbers of HMO subjects who were at or above 15 $\mu\text{g}/\text{dL}$ were too small for statistical analysis. Where appropriate, the data are reported as HMO, non-HMO, and total sample.

RESULTS

Blood Lead Levels

Children with WBLs at or above levels of 10, 15, and 20 $\mu\text{g}/\text{dL}$ were roughly 5 to 10 times as common in the non-HMO settings, compared with those in the HMO. Rates ranged from 15½% at 10 $\mu\text{g}/\text{dL}$ to 1.5% at 20 $\mu\text{g}/\text{dL}$ in the non-HMO group and from 3.5% to 0.17% in the HMO group. Details are shown in Fig 2. At WBL levels of 10 $\mu\text{g}/\text{dL}$ and 15 $\mu\text{g}/\text{dL}$, the non-HMO group was at higher risk for elevated lead levels ($P < .0001$ at 10; $P < .001$ at 15, respectively).

For both the HMO the non-HMO sample the proportion of elevated levels was greatest for the 1- and 2-year-olds.

The population was identified by site of medical care. Some sites serve groups of children who are at very high risk. The Homeless Shelter site in Minneapolis had two fifths of patients with WBLs ≥ 10 , the Indian Health Board site had one third of patients with WBLs ≥ 10 and 8% with WBLs of ≥ 20 , and Minneapolis Children's Hospital and North End Clinic both had one fourth of patients with WBLs ≥ 10 .

Questionnaire and Demographic Results

Items on the questionnaire were analyzed to see if there was an association with elevated lead levels. Using univariate analysis, only one item, regarding distance from a lead emitting factory did not achieve statistical significance. Questions with the highest odds ratios were the following: a personal or sibling history of lead poisoning, a history of eating paint

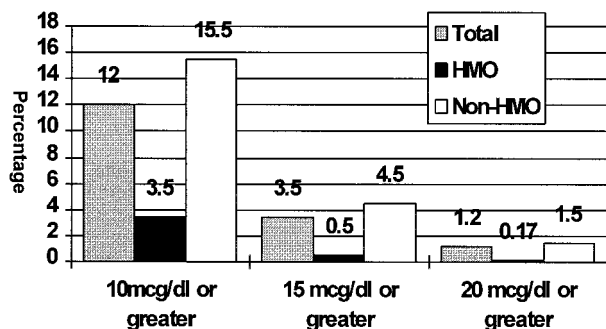


Fig 2. Percentage of blood leads greater than specified cutoff values.

chips, and living in a home built before 1950 or of unknown age.

In three questions >2% answered "don't know." In the non-HMO sample, >2% answered "don't know" to age of housing. Those living in housing of unknown age (almost all of whom were in the non-HMO sample) had rates of elevated WBLs almost identical to those living in housing built before 1950. Thus, in the analysis these two groups are combined.

In both samples >2% answered "don't know" to proximity to a lead emitting factory and to daycare built before 1950. However, because these questions were not significant predictors when logistic regression was performed, no further analysis was done.

Using stepwise logistic regression, at a cutoff of 10 $\mu\text{g}/\text{dL}$, the following four questions remained significant. Thus, these questions are used in further analysis:

1. Have you ever been told your child has lead poisoning?
2. Does your child have a sibling or housemate who has had lead poisoning?
3. Within last 6 months has your child lived in a home built before 1950?
4. Have you ever seen your child eat paint chips?

The questionnaire, demographic data, and geographic data were assessed together using stepwise logistic regression at the levels of 10 $\mu\text{g}/\text{dL}$ and 15 $\mu\text{g}/\text{dL}$.

For the cut off of 10 $\mu\text{g}/\text{dL}$, in order of descending odds ratios, the following factors were significant for the population as a whole and the non-HMO population. (Questionnaire items are presented as questions; see Table 2).

1. Have you ever been told your child has lead poisoning?
2. Have you ever seen your child eat paint chips?
3. Does your child have a sibling or house-mate who has had lead poisoning?
4. Within last 6 months has your child lived in a home built before 1950?
5. Poverty status (as defined geographically)
6. Native American or African-American race
7. Living in a dwelling for <6 months
8. Living in Minneapolis or St Paul

For children who were in the low-risk HMO population, at a cutoff of 10 $\mu\text{g}/\text{dL}$, the following factors were significant in order of decreasing odds ratios:

1. Have you ever been told your child has lead poisoning?
2. Native American race.
3. Have you ever seen your child eat paint chips?
4. Within last 6 months has your child lived in a home built before 1950?
5. Poverty status (as defined geographically).

At 15 $\mu\text{g}/\text{dL}$, the analysis was performed only for non-HMO and total populations. Again, in order of descending odds ratios, the following factors were significant for both analyses (see Table 3):

TABLE 2. Odds Ratios From Logistic Regressions Modeling Lead Levels Above and Below 10 $\mu\text{g}/\text{dL}$. (Stepwise Selection of Variables)

| Variables | HMO Only | 95% CI | Non-HMO | 95% CI | All Children | 95% CI |
|--|----------|------------|---------|-----------|--------------|-----------|
| Positive factors | | | | | | |
| Told of child having lead poisoning | 15.29‡ | 3.38–69.06 | 5.87‡ | 4.36–7.91 | 6.00‡ | 4.47–8.05 |
| Eat paint chips | 3.42* | 1.14–10.32 | 2.22‡ | 1.54–3.20 | 2.27‡ | 1.61–3.22 |
| Living in house built before 1950 | 2.64‡ | 1.60–4.36 | 1.46‡ | 1.21–1.77 | 1.54‡ | 1.28–1.84 |
| Told of siblings having lead poisoning | | | 1.64‡ | 1.28–2.11 | 1.62‡ | 1.27–2.07 |
| 20% poverty tract | 1.85* | 1.01–3.38 | 1.46‡ | 1.19–1.79 | 1.49‡ | 1.23–1.81 |
| Race^a | | | | | | |
| Native American | 4.85* | 1.26–18.62 | | | 1.47* | 1.05–2.06 |
| African-American | | | | | 1.24* | 1.02–1.52 |
| Negative factors | | | | | | |
| Duration in home | | | .83‡ | .754–.916 | .82‡ | .751–.904 |
| Sex ^b | | | .79† | .673–.940 | .81† | .691–.944 |
| HMO Indicator | | | | | .52‡ | .402–.669 |
| Residence^c | | | | | | |
| Suburban Ramsey County | | | .76† | .622–.924 | .81* | .673–.979 |
| Dakota County | | | .61† | .437–.853 | .68* | .501–.924 |
| Suburban Hennepin County | | | .38‡ | .252–.586 | .41‡ | .282–.582 |
| Washington County | | | .25‡ | .123–.499 | .35‡ | .197–.618 |

^a White is the reference group.

^b Male is the reference group.

^c Residing in Minneapolis is the reference group.

Statistical significance: * < .05; † < .01; ‡ < .001.

TABLE 3. Odds Ratios from Logistic Regressions Modeling Lead Levels Above and Below 15 $\mu\text{g}/\text{dL}$. (Stepwise Selection of Variables)

| Variables | Non-HMO | 95% CI | All Children | 95% CI |
|--|---------|-----------|--------------|-----------|
| Positive factors | | | | |
| Told of child having lead poisoning | 4.94‡ | 3.34–7.31 | 5.00‡ | 3.39–7.37 |
| Eat paint chips | 2.76‡ | 1.67–4.55 | 2.82‡ | 1.72–4.59 |
| Living in house built before 1950 | 1.53* | 1.08–2.16 | 1.51* | 1.08–2.09 |
| Told of siblings having lead poisoning | 2.04‡ | 1.40–2.98 | 2.02‡ | 1.39–2.94 |
| 20% Poverty tract | 1.78‡ | 1.26–2.53 | 1.84‡ | 1.31–2.60 |
| Race^a | | | | |
| Native American | 1.82* | 1.09–3.06 | 1.85* | 1.11–3.07 |
| Negative factors | | | | |
| Duration at home | .81* | .687–.966 | .80† | .679–.947 |
| HMO Indicator | | | .44† | .249–.766 |

^a White is the reference group.

Statistical significance: * < .05; † < .01; ‡ < .001.

1. Have you ever been told your child has lead poisoning?
2. Have you ever seen your child eat paint chips?
3. Does your child have a sibling or housemate who has had lead poisoning?
4. Within last 6 months has your child lived in a home built before 1950?
5. Poverty status (as defined geographically).
6. Native American race.

Native American children had the highest prevalence of elevated WBLs at all levels, followed by black, Hmong, Hispanic, and white children. At a cut off of 10 $\mu\text{g}/\text{dL}$, the prevalence for Native American, black, Hmong, Hispanic, and white children ranged from 27%, to 7% ($P = .000001$; see Fig 3).

Poverty played a crucial role in the elevation of WBLs. Poverty census tracts were defined by using a cutoff of both 10% and 20% of the families in that tract living below federal poverty levels. Making dichotomous cuts at both levels showed that children in census tracts defined as poverty areas had almost double the risk of elevated lead levels.

Housing was another crucial variable. Living in housing built before 1950 or of unknown age (as

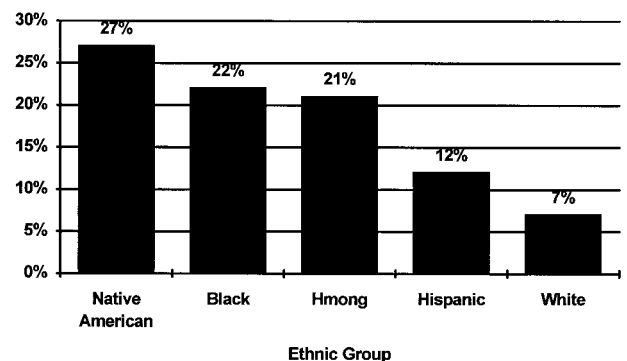


Fig 3. Percentage of blood leads 10 $\mu\text{g}/\text{dL}$ or more by ethnic group.

determined by questionnaire) doubled the percent of children with elevated WBL levels at all cutoff points. Rates for pre-1950 housing and housing of unknown age were identical. Length of time in current dwelling was a strong predictor of elevated WBL levels. Children living in their current dwelling <6 months compared with those residing in their home >1 year had a two- to threefold increased risk.

DISCUSSION

This study adds to the understanding of the distribution of WBLs in the twin cities metropolitan area. Children at highest risk in this sample were those who were racial minorities, living in poverty, residing in the central city, living in housing built before 1950 or of unknown age, and those who had a history of or a sibling with a history of lead poisoning.

Significant limitations exist for this study. It is not based on a random sample of the population. The age distribution between the two subsamples differed. At all sites where fingerstick WBLs were drawn, few confirmatory venous samples were quickly obtained. The results from this study may not be generalizable to many other metropolitan areas. However, metropolitan areas in this part of the country with similar population and housing demographics are likely to have similar distribution of elevated WBLs.

Because of the oversampling of high-risk children, the results probably represent an upper limit estimation of the true prevalence of elevated WBLs in our community. Being a member of a racial or ethnic minority increased the risk of elevated WBLs.

Poverty status was also associated with increased elevated WBLs. Living in a census tract with either >10% or >20% of families below the federal poverty level resulted in substantial increased risk. Almost all the poverty census tracts defined by 10% or 20% of the population living in poverty were located in Minneapolis and St Paul, and not in the suburbs. This information can be used to design a screening strategy.

The high predictive value of eating paint chips and the age of housing suggest that lead paint is the primary source of lead. Before 1950, no regulation of paint lead content occurred in this country, and many paints were in the range of 30% to 50% lead by dry weight. In 1950 the allowable amount of lead by dry weight was 5%. In subsequent years, that figure has been lowered further by two orders of magnitude. In 1977 lead was no longer allowed in paint.

Living in a dwelling for <6 months was highly correlated with an increased risk of lead poisoning in

a child. Although we do not understand this unexpected finding, we suggest two possible explanations: 1) increased mobility may be serving as a marker of poverty, and 2) substantial amounts of remodeling of housing occurs in the first 6 months (Minnesota Department of Health, unpublished data) and may make lead in the environment much more accessible.

The population was defined by site of medical care. Using site of care to define risk groups of children for lead poisoning is very powerful for three reasons. First, as was demonstrated in this study, some populations defined this way are at very high risk. Second, because the risk is so concentrated in some of the sites of this study, any program that has impact on the highest risk children will be directly measurable at these sites. Third, it is likely that interventions centered at these sites will have immediate impact.

Understanding the distribution of elevated WBLs is an important first step in lead poisoning prevention. Frankenberg and Camp,⁵ in their classic text on screening, make it clear that testing by itself is inadequate. To be most effective, a screening program for lead poisoning needs to include a screening strategy, a tracking system for both children and housing, and a treatment program for both children and housing.

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