Rural-Urban Blood Lead Differences in North Carolina Children

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ABSTRACT. ***Objective.*** **To examine the prevalence of and risk factors for having a blood lead elevation among young children in a predominantly rural state.**

Methods. **20 720 North Carolina children at least 6 months and <6 years of age were screened between November 1, 1992 and April 30, 1993 using either capillary or venous measurements of blood lead. Children were tested through routine screening programs that target low-income families and, hence, were not randomly selected. Eighty-one percent of the children were screened through local public health departments, and 19% were tested at private clinics.**

Results. **The estimated prevalences of having an elevated blood lead level among those tested were: 20.2% (≥10 μg/dL), 3.2% (≥15 μg/dL), and 1.1% (≥20 μg/dL). Black children were at substantially increased risk of having a blood lead ≥15 μg/dL (odds ratio (OR) = 2.1, 95% confidence interval (CI) = 1.7 to 2.5). Children aged 2 years old had an elevated risk (OR = 1.4, 95% CI = 1.1 to 1.7) compared to 1-year-olds, and males were at slightly increased risk (OR = 1.2, 95% CI = 1.0 to 1.4). Living in a rural county was nearly as strong a risk factor as race (OR = 1.9, 95% CI = 1.6 to 2.4). The effect of rural residence was even greater among certain subgroups of children already at highest risk of having an elevated blood lead. The type of clinic (public vs private) where a child was screened was not associated with blood lead outcome. These same trends were seen for children with blood lead levels ≥20 μg/dL.**

Conclusions. **Among children screened from rural communities, the prevalence of elevated blood lead is surprisingly high. Though few physicians have embraced universal lead screening, these data support the need for greater awareness of lead exposure in children living outside of inner-cities.** ***Pediatrics*** **1994;94:59–64;** ***lead poisoning, blood lead, children.***

ABBREVIATIONS. OR, odds ratio; CI, confidence interval; CDC, Centers for Disease Control and Prevention.

In response to increasing evidence supporting the toxicity of lead at blood levels <25 μg/dL,[1–3] the Centers for Disease Control and Prevention (CDC) has lowered the level of blood lead for which intervention is recommended from 25 μg/dL to 10 μg/dL and recommended universal screening of young children using direct blood lead measures.[4] The American Academy of Pediatrics endorsed the CDC recommendations in April 1993.[5] However, some pediatricians have challenged the need for universal screening on the grounds that: 1) the prevalence is too low to warrant the expense, 2) there is no treatment for low level poisoning, and 3) scarce resources can be used more effectively.[6–9]

The CDC acknowledges that local epidemiologic data are needed to better define high-risk populations. Based on sound prevalence data, the need for lead screening in inner-city, minority, low-income populations is well accepted. However, there are only a few historical reports of the prevalence of elevated blood lead in nonurban areas,[10–12] and these were conducted before federal legislation mandating the removal of lead from gasoline and the subsequent decline in lead exposure to the general public.[13]

Historically in North Carolina, screening for childhood lead poisoning has occurred at local health departments in both urban and rural areas.[14] Only 37.9% of the state's 6.6 million residents live in urbanized areas of >50,000 population. Statewide there is a large black population (22%), however, the percentage is even greater in urban counties (25%). In terms of other potential risk factors for lead poisoning, rural counties have a greater percentage of older housing and children in poverty.[15]

In October 1992, North Carolina implemented new lead screening recommendations calling for the screening of all children seen at local health departments for health maintenance visits and all children receiving Medicaid services through private providers at least once before the age of 6 years. At the same time, direct blood lead measurement replaced the less sensitive and less specific erythrocyte protoporphyrin screening test.

Since the new recommendations have gone into effect, screening has more than doubled. This increase in screening activity, and the use of blood lead determinations, offered the opportunity to assess more accurately the importance of low and moderate level lead poisoning in this region.

The purposes of this study were to: 1) assess the prevalence of having a blood lead elevation among children screened for lead poisoning in a state with a large rural population and 2) identify risk factors for elevated blood lead levels in children living in a

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predominantly nonurban state. It was hypothesized that the prevalence of elevated blood lead levels among children screened in North Carolina would be lower than those reported from urban screening programs yet high enough to warrant universal screening.

METHODS

Laboratory test results were reviewed for children receiving a blood lead screening test through the North Carolina State Laboratory of Public Health and the Wake County Health Department from November 1, 1992 through April 30, 1993. Children were tested through routine screening programs and were primarily children receiving health care through their local health departments and Medicaid-eligible children seen at private clinics. Thus, the target population consisted of low-income children.

Infants <6 months of age and children 6 years of age or older were excluded for this analysis. Only the initial screening test was considered for children who were tested more than once during this period. In addition, children identified before November 1, 1992 as having a blood lead level ≥10 μg/dL were excluded, because testing among these children constitutes case follow-up as opposed to initial screening. However, few children were excluded from either rural or urban areas as a result of prior case status because the erythrocyte protoporphyrin screening test that was used before November 1992 identified <1% of children screened as having blood leads ≥10 μg/dL.[14] In total, there were 20 720 children meeting the selection criteria.

Although there is some screening conducted through commercial laboratories, the two public health laboratories used in this study combine to serve the vast majority (>95%) of young children screened in the state. Both laboratories conduct blood lead analysis using atomic absorption spectrophotometry. Instrumentation for both laboratories was purchased from and is calibrated by the same manufacturer. An identical sample preparation protocol is used at each laboratory further reducing the likelihood of interlaboratory variability.

The following information was available for each child: date of birth, race, sex, county of residence (street address was not available), date of collection, clinic where the blood specimen was collected and type of specimen (capillary or venous). Eight counties with the highest percentage of urban population according to the 1990 census were defined as urban for this analysis. Each of these counties contains a recognized urban center and has a population density ≥400 persons per square mile. These counties combined account for >36% of the state's 557,533 children <6 years old. The remaining 92 counties were defined as rural.

Odds ratios (ORs) for having a blood lead level ≥15 μg/dL (the level for which the CDC recommends individual case management) were computed for age, race, sex, type of clinic, and county of residence population density. The number of venous specimens collected was insufficient (484 children were screened by venous specimen, 18 of these children had blood leads ≥15 μg/dL) to evaluate the effect on blood lead of having a venous vs a capillary blood specimen drawn. ORs for each variable were adjusted for other potential confounders using unconditional multiple logistic regression modeling. Similar analyses were performed defining an elevated blood lead as ≥20 μg/dL (the level for which the CDC recommends more aggressive medical and environmental interventions).

RESULTS

Demographic characteristics of the study population are described in Table 1. Relevant statistics for the state of North Carolina are also provided for comparison. Children screened were disproportionately 1 year of age, black, screened at public clinics, and residents of rural counties. The mean age was just over 2 years.

The distribution of children with elevated blood lead levels stratified by urban versus rural counties is shown in the Figure. The estimated statewide prevalences of having an elevated blood lead among children tested were: 20.2% (≥10 μg/dL), 3.2% (≥15 μg/dL), and 1.1% (≥20 μg/dL). The estimated prevalence was higher for residents of rural counties at every cutpoint. The mean blood lead level for all children screened was 7.4 μg/dL; the 75th percentile was 9 μg/dL; the 90th percentile was 11 μg/dL. Seasonal effects on blood lead were not indicated by the variation in mean blood lead level over the 6-month period.

TABLE 1. Characteristics of Children Screened for Lead Poisoning and Relevant North Carolina Statistics

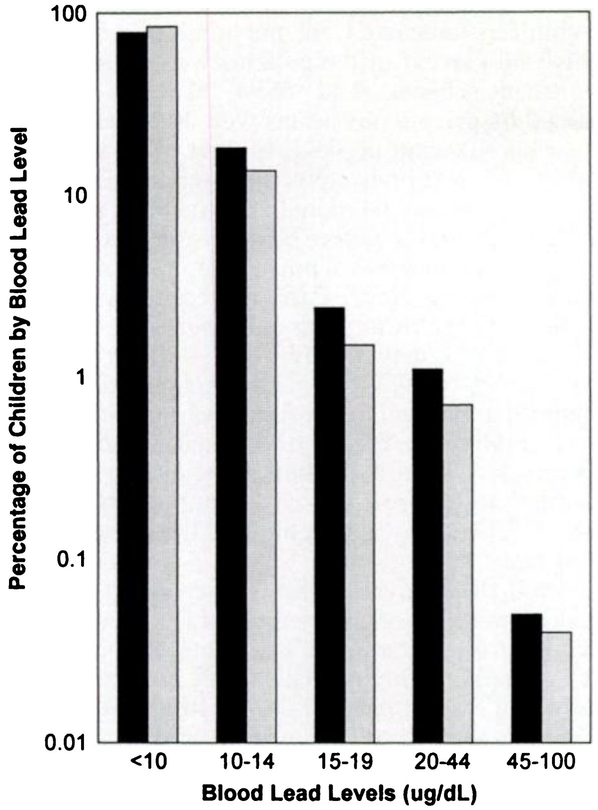
Variable	Study Population		North Carolina,
	n,	(%)	(%)*
Age			
6 to 12 mo	1 106	5.3	9.8
1 y	7 003	33.8	18.8
2 y	4 217	20.4	18.3
3 y	3 120	15.1	17.7
4 y	3 125	15.1	17.9
5 y	2 149	10.4	17.4
Race			
White	8 052	38.9	69.7
Black	10 623	51.3	27.8
Other	1 297	6.3	2.6
Missing	748	3.6	
Sex			
Female	9 911	47.8	49.0
Male	10 593	51.1	51.0
Missing	216	1.0	
Type of Clinic			
Private	3 897	18.8	60†
Public	16 823	81.2	40†
Residence			
Urban county	5 668	27.4	36.1
Rural county	15 052	72.6	63.9

* Percent for children from 6 months up to 6 years old.
† Percent of children who receive well child care in this clinic setting.

The percentages of children with elevated blood lead levels for each category of the potential risk factors are shown in Table 2. The prevalence of elevated blood leads among those tested appears to peak at age 2; fully 25% of 2-year-olds have blood lead levels ≥10 μg/dL; 4.5% have levels ≥15 μg/dL compared with 1.9% of 5-year-olds. Black children are twice as likely as white children to have a blood lead level ≥15 μg/dL, with prevalence among children of other races intermediate between the prevalences for whites and blacks. The prevalence of an elevated blood lead level in males is slightly greater than in females; blood lead outcome does not differ appreciably for children screened in public as compared with private clinics.

Adjusted ORs and 95% confidence intervals (CIs) for the associations between elevated blood lead and potential risk factors are listed in Table 3. Adjustment for the other variables listed in the table did not appreciably alter any of the crude ORs (not shown).

Age had a significant effect on the risk of having an elevated blood lead. Children aged 2 years were at greatest risk of having a blood lead level ≥15 μg/dL (OR = 1.4, 95% CI = 1.1 to 1.7) compared



Rural ■	78.1	18.2	2.4	1.1	0.05
Urban ☐	84.2	13.6	1.5	0.7	0.04
Statewide	79.8	17.0	2.2	1.0	0.05

Figure. Distribution of blood lead levels stratified by urban versus rural counties.

TABLE 2. Percentage of Children with Elevated Blood Lead Levels (μg/dL)

Variable	≥10	≥15	≥20
Age			
6 to 12 mo	13.0%	1.7%	0.7%
1 y	21.1%	3.2%	0.9%
2 y	25.2%	4.5%	1.6%
3 y	22.2%	3.8%	1.3%
4 y	16.5%	2.5%	0.7%
5 y	13.7%	1.9%	0.8%
Race*			
White	14.6%	2.1%	0.8%
Black	24.7%	4.1%	1.2%
Other	18.6%	3.0%	1.0%
Sex*			
Female	19.1%	2.9%	1.0%
Male	21.2%	3.5%	1.1%
Type of Clinic			
Private	20.7%	2.9%	1.0%
Public	20.1%	3.3%	1.1%
Residence			
Urban county	15.8%	2.2%	0.7%
Rural county	21.9%	3.6%	1.2%

* There are missing values for this variable (see Table 1).

with 1-year-olds. Children <1 year old had a reduced risk (OR = 0.5, 95% CI = 0.3 to 0.9) as did 5-year-olds (OR = 0.6, 95% CI = 0.4 to 0.8). The arbitrary 1 year old reference age was chosen because this is the primary target screening population (12 to 24 months of age), and the largest percentage of children in this screening population were in this category. Black children were at substantially increased risk relative to white children (OR = 2.1, 95% CI = 1.7 to 2.5). Children of other races (37% of whom were American Indian) also had an elevated risk (OR = 1.5, 95% CI = 1.1 to 2.2). Gender had a modest association with blood lead outcome with males at slightly increased risk (OR = 1.2, 95% CI = 1.0 to 1.4). The type of clinic (public vs private) where the blood specimen was collected did not affect the blood lead outcome.

The relation between population density and elevated blood lead (≥15 μg/dL) was nearly as great as that of race and blood lead. Contrary to generally held assumptions about the epidemiology of childhood lead poisoning, it was the rural children in North Carolina who were at increased risk (OR = 1.9, 95% CI = 1.6 to 2.4).

Race and gender were found to be effect modifiers and age was a slight confounder of this association. The results of logistic regression modeling indicate that when these other covariates are accounted for, the effect of rural residence is even greater for certain subgroups. Black males, already at highest risk for having an elevated blood lead, have the greatest additional risk as a result of living in a rural vs urban county (OR among black males = 2.6, 95% CI = 1.9 to 3.6).

These same trends were evident when using a cutpoint of ≥20 μg/dL to define an elevated blood lead. The effect of age was somewhat stronger: 2-year-olds were at increased risk (OR = 1.7, 95% CI = 1.2 to 2.4) relative to 1-year-olds. Black children were still at increased risk (OR = 1.6, 95% CI = 1.2 to 2.2). Males were at increased risk, but this finding was no longer significant. The association with population density was virtually identical (OR = 2.0, 95% CI = 1.4 to 2.9), and again, type of clinic was unrelated to blood lead outcome.

DISCUSSION

The data show that 20.2% of screened children had blood lead levels ≥10 μg/dL, the lowest level of concern identified by the CDC. Race (nonwhite), residence (rural), age (2 years old) and gender (male) were all associated with having a blood lead elevation. Findings of higher lead levels in nonwhite, male and 2-year-old children have been described previously.[16] In addition, in the population-based NHANES II Survey conducted 1976 through 1980, rural black children had a higher prevalence of elevated blood lead than urban black children. However, the opposite relation was observed in white children of the same ages, among whom central city residents in urban areas of 1 million persons or more had the higher prevalence of elevated blood lead. The unique finding in this North Carolina study population is that children living in rural counties are at increased risk of having an elevated blood lead compared with children living in urban counties, regardless of race. Moreover, although both white and black children

TABLE 3. Selected Characteristics and Associated Odds Ratios of Having an Elevated Blood Lead Level

Variable	Adjusted OR (95% CI)*			
	≥15 μg/dL		≥20 μg/dL	
Age				
6 to 12 mo	0.5	(0.3 to 0.9)	1.0	(0.5 to 2.0)
1 y†	1		1	
2 y	1.4	(1.1 to 1.7)	1.7	(1.2 to 2.4)
3 y	1.1	(0.9 to 1.4)	1.3	(0.9 to 2.0)
4 y	0.8	(0.6 to 1.0)	0.8	(0.5 to 1.3)
5 y	0.6	(0.4 to 0.8)	0.9	(0.5 to 1.5)
Race				
White†	1		1	
Black	2.1	(1.7 to 2.5)	1.6	(1.2 to 2.2)
Other	1.5	(1.1 to 2.2)	1.3	(0.7 to 2.4)
Sex				
Female†	1		1	
Male	1.2	(1.0 to 1.4)	1.2	(0.9 to 1.5)
Type of Clinic				
Private†	1		1	
Public	1.1	(0.9 to 1.4)	1.0	(0.7 to 1.5)
Residence				
Urban county†	1		1	
Rural county	1.9	(1.6 to 2.4)	2.0	(1.4 to 2.9)

* Adjusted for all other variables in table. OR, odds ratio; CI, confidence interval.
† Reference category.

experience a higher prevalence of elevated blood lead if they reside in rural counties, the difference is greater for black children.

Two other recent studies have reported percentages of children with elevated blood lead levels from rural areas. Using data collected in 1992, Weismann et al[17] reviewed the experience of 570 children in Iowa from portions of the state outside of the four largest cities. These children were screened by primary care physicians during routine health maintenance examinations, and consistent with this study's findings, 23.9% had blood lead levels ≥10 μg/dL. Rifai et al[18] reported that the incidence of elevated blood leads differed widely based on geographic area for 4 528 inner-city, suburban, and rural children in and around Washington, DC. The percentages of children with blood lead levels ≥10 μg/dL were 18.6% (inner-city), 2.4% (suburban), and 5.8% (rural). Although this study reported a much lower percentage of elevated blood lead among suburban and rural children, these children differed substantially from the inner-city children in racial composition and socioeconomic status.

What might account for the finding in this study of an increased risk for blood lead elevation among rural children? The main current source of lead exposure to children is deteriorating paint in older housing, and 1990 county summary census data indicate that the percentage of pre-1950 housing is greater in rural North Carolina (19.6%) than in urban areas (14.5%). The percentage of children in poverty is also higher in rural versus urban counties, 20.5% and 16.0%, respectively.[15,19] Moreover, in North Carolina counties with urban centers, there are large suburban areas where housing is relatively new and less likely to contain leaded paint.

There are several limitations to this study. First, the children screened were not randomly selected. Eighty-one percent of the patients were local health department clients, and most of the children screened by private physicians were Medicaid recipients. This selection process resulted in a sample of children of relatively low socioeconomic status. These children may be more likely to live in substandard housing and therefore be at greater risk for lead exposure than the general population. However, 40% of all children in North Carolina receive well child care in local health departments (personal communication, B. Goldstein, Division of Maternal and Child Health, NCDEHNR). The average pediatrician and family physician in the state sees a high percentage of children covered by Medicaid, 30 and 21%, respectively.[20] Thus, even though the results may not generalize to all preschool children, the target population of this study is roughly half the preschoolers in this state.

Second, the analysis relied on screening test results; confirmation of elevated blood leads by venous specimen was not required. It is generally presumed that the capillary fingerstick sample collection procedure will result in more false positive results than the venous sample collection method due to potential contamination by lead on the finger surface. However, one recent study has reported a high correlation between venous and capillary specimens drawn simultaneously from a pediatric population, with mean capillary-venous differences <1 mg/dL.[21] Although a strict sample collection protocol recommended by the CDC[4] is followed by all clinics included in this study, simultaneous venous and capillary specimens were not drawn for any children screened. However, an indirect comparison of the two collection procedures indicates that venous specimens do not necessarily provide more conservative blood lead measurements. Within 6 months after the screening period for this study, 580 of the 671 children with blood leads ≥15 μg/dL had been retested (339 by venous specimen, 202 by capillary specimen and 39 by unknown collection method). Although the reduction in mean blood lead was substantial for all children retested, it did not differ appreciably according to method of sample collection. The mean blood lead reduction for a venous versus capillary retest was 5.4 μg/dL and 4.8 μg/dL, respectively. This small difference suggests that contamination was not a major factor.

Moreover, analysis restricted to cases confirmed by venous testing did not substantially alter the results. Children residing in rural counties were still at significantly elevated risk for having a blood lead ≥15 μg/dL (OR = 1.7, 95% CI = 1.2 to 2.4) as were black children and 2-year-olds. For these reasons and because venous testing was only conducted on those with elevated screening tests, the original screening test blood lead levels available for the entire study population were used.

Third, these data were collected in one state, a factor that may limit its generalizability. For example, patterns of blood lead elevation in North Carolina may differ substantially from those in states with large urban centers. However, the prevalence data from this study are similar to the recent findings from Iowa.[17] Furthermore, the rural excess of elevated blood lead among black children echos a similar finding in a national probability sample during the period when restrictions on leaded gasoline were being implemented.[12] It is reasonable to suggest that the results generalize to other states where rural poverty and deteriorated housing conditions are also widespread.

Fourth, rural/urban exposure classification was based on an ecologic measure, namely countywide population density. The interpretation of these results, therefore, is that children living in primarily rural counties are at higher risk for having a blood lead elevation than children living in primarily urban counties. Individual addresses were not available in the dataset analyzed. Therefore, some misclassification may have occurred in classifying children as urban or rural based on overall county population density. However, it is unlikely that this misclassification significantly altered the results because <16% of the study population is estimated to have been misclassified using the Census Bureau's definition of "urbanized areas."[15] If the misclassification were nondifferential, the association between individual rural residence and elevated blood lead would have been underestimated in this study. If misclassification were differential, it is possible that there is no association with rural/urban residence defined at the individual level, but only if the misclassification rates differ substantially between those with elevated blood leads and those with lower levels.

Moreover, both county-wide classification and individual residence status are surrogate measures for something else: population density does not itself increase the level of lead in blood. Ruralness may be a surrogate for factors associated with age of housing, which in turn may be the true causative agents. Furthermore, using a county-level variable is more meaningful for prevention purposes. Surveillance programs and public health services are administered at the county level. Understanding county-level factors as contributors to health risks can enable a rational allocation of funds.

Many physicians, particularly in nonurban areas, feel that the prevalence of elevated blood lead in their community is too low to warrant the effort and expense of screening all children. Local data on the prevalence of elevated blood lead and the CDC questionnaire to assess risk[4] are two aids that can be used to target patients at higher risk. However, local prevalence data are often unavailable, and the sensitivity and specificity of the CDC screening questionnaire are, at this time, unclear. Although the data presented in this paper cannot serve as local prevalence data (because they are not population-based), they demonstrate that even children living in rural communities can have a surprisingly high prevalence of elevated blood lead and in some cases, their risk of blood lead elevation may be higher than among urban children.

Many physicians are concerned that screening for lead poisoning is not worthwhile since, clinically, little can be done for children identified with low and moderate level lead poisoning (≤45 μg/dL). However, according to federal recommendations,[4] the 20.2% of children in this study with blood lead levels ≥10 μg/dL should receive periodic rescreening in addition to the anticipatory guidance about lead poisoning recommended for all young children; the 3.2% with levels ≥15 μg/dL should receive retesting every 3 to 4 months, a complete nutritional assessment and parental education on the sources of lead; the 1.1% with levels ≥20 μg/dL should receive more involved medical and environmental interventions aimed at: 1) reducing the child's absorption of lead (eg, treating calcium and iron deficiency), and 2) identifying the source of exposure and removing the child from the source (eg, environmental investigation and abatement).

In conclusion, the data reported here suggest that children living in some rural areas are at increased risk of having a blood lead elevation. Further work identifying such areas as well as the reasons for the elevations in blood lead is warranted. Adoption of universal screening will enable health officials to gather local prevalence data. Within several years, this strategy will help to identify communities with substantial lead problems so that screening can then be more accurately targeted.

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JUDGE RULES IN FAVOR OF ABBOTT LABORATORIES IN FTC INFANT FORMULA CASE

A Federal District Court Judge has ruled that Abbott Laboratories is not guilty of anti-competitive behavior in a case brought by the Federal Trade Commission (FTC) related to Abbott's infant formula contract bidding practices in Puerto Rico.

In a written opinion filed May 27, Judge Stanley Sporkin, United States District Court for the District of Columbia, said: "Abbott's conduct was a model of how a responsible major public corporation should act under investigation by a government agency."

Charges brought by the FTC in June, 1992, alleged that Abbott conspired with its principal competitors in bidding the 1990 Puerto Rico Special Supplemental Food Program for Women, Infants and Children (WIC) contract, and that Abbott engaged in unfair methods of competition by providing information to competing bidders.

"The FTC would have the Court find that after behaving properly in two instances where its competitors did not so behave, Abbott changed its corporate mindset, and joined a collusive plan to submit a noncompetitive bid," wrote Judge Sporkin. "To the contrary, the Court does not find that Abbott exhibited the 'conscious commitment to a common scheme' that is a required element of an illegal conspiracy," according to Judge Sporkin's opinion.

The charges brought by the FTC against Abbott followed a 2-year investigation of the infant formula market by the FTC's Bureau of Competition in which more than 80 WIC bidding situations were reviewed.