Small Area Analysis of Risk for Childhood Lead Poisoning

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Abstract

Objectives

Although mean blood lead (BPb) levels in the United States continue to decrease, there is evidence that certain populations, particularly young children living in communities with a high proportion of older, poorly maintained housing, remain at high risk for lead exposure. The objective of this study is to describe and compare the prevalence rates of elevated childhood BPb levels in relatively small geographic areas within seven US cities.

Methods

Data on the number of children who received BPb tests and the number of children identified with elevated BPb ($\geq$ 10 µg/dL), by ZIP code, were collected from state or local health departments. The number of children less than six years of age living in each ZIP code was extracted from the 1990 US census. We calculated the city-wide mean percent of children with BPb $\geq$ 10 µg/dL for each city and compared these to the percent of children with BPb $\geq$ 10 µg/dL, by ZIP code, within the same city.

Results

- A total of 27,603 (19.5%) of the children tested in the seven cities had BPb $\geq$ 10 µg/dL.
- In each city, most of the children with elevated BPb were concentrated in relatively few ZIP codes. In six of the cities, we found that 50% of the children with elevated BPb levels lived in fewer than 25% of the city's ZIP codes.
- For the entire sample of 229 ZIP codes, there were 200 (87.3%) ZIP codes where the percentage of children with BPb $\geq$ 10 µg/dL was > 4.4%, the average for the US childhood population less than six years old, as estimated during the second phase of NHANES III (1991-1994).
- Rates of elevated BPb levels at the ZIP code level ranged from below the national average to more than 10 times higher.

Conclusions

For many children, the risk for lead exposure remains very high. In every city, we found wide disparity among ZIP codes in the prevalence rates of elevated BPb levels among tested children. The prevalence rates in ZIP codes with the highest rates significantly exceeded prevalence rates at the city, state, and national levels. We conclude that analyses of childhood BPb data performed at the ZIP code level can provide valuable information for targeting resources to the highest risk communities. Analyses conducted at larger geographic levels, such as at the state or city level, can mask disparities among communities, camouflage pockets of high risk, and hinder targeting of resources to places with the greatest problem.

Introduction

Childhood lead poisoning is a major environmental health problem that causes adverse effects on children's development and later success as adults.[1–4] Exposure to lead harms children's cognitive development, behavior, and growth. Harmful effects have been clearly demonstrated at blood lead (BPb) levels of 10 µg/dL, and the BPb threshold below which there are no harmful effects has not been established.[5] In the United States, the most common source of exposure is deteriorating lead-based paint in older homes that are in poor condition. Young (12–36 months of age), minority children in low-income families in distressed urban communities are most likely to be exposed to lead hazards at home.[6] Most commonly, toddlers and young children are exposed when they ingest small amounts of lead-contaminated house dust during normal hand-to-mouth behavior.[7]

A notable aspect of childhood lead poisoning in the United States is the extremely uneven distribution of risk factors for lead exposure among neighborhoods within cities. For example, the proportion of housing built before 1950 (an important risk factor for lead exposure) can vary dramatically from neighborhood to neighborhood within the same city. As a result, in some communities the reported rates of elevated childhood BPb levels are much higher than the national rate and much higher than rates in neighboring communities.[8]

Decline in the proportion of children with elevated BPb level at the national level. The proportion of US children with elevated BPb ($\geq$ 10 µg/dL) has been declining, documented by the periodic population survey known as the National Health and Nutrition Examination Survey (NHANES). NHANES data reveal that the proportion of US children with elevated BPb fell from 88.2% (NHANES II, 1976 to 1980), to 4.4% (NHANES III, Phase 2, 1991 to 1994).[9] Data from NHANES 1999 indicate that the geometric mean BPb level for all US children has decreased from 2.7 to 2.0 µ/dL in the years since the second phase of NHANES III, suggesting a further decline in proportion of US children with elevated BPb.[10]

Decline in the proportion of tested children with average BPb $\geq$ 10 µg/dL at the state level. Some states have reported reductions in rates of childhood BPb elevations similar to those documented in the NHANES surveys. A recent report showed that among children less than 6 years of age who received BPb tests in 19 states during 1997-1999, there was an average decrease in the percent of children with elevated BPb, from 10.5 % in 1997 to 7.6 % in 1999.[10]

BPb data reported at the city level. At least one report on children's BPb elevations from the local level is dramatically less encouraging than the national and state reports. A review of surveillance data for the city of Chicago during the period 1993-1997 showed no decrease in the number of children identified as having BPb elevations over this 5-year period.[11] To better illuminate disparities in risk for lead poisoning, we performed a cross-sectional analysis of the risk of elevated BPb by ZIP code for seven cities located in the United States. Our findings suggest that in some cities and especially in certain ZIP codes within cities, the problem of childhood lead poisoning remains a major public health concern that continues to threaten the future of many children in our nation's most distressed communities.

Methods

Cities Included In Our Study

We assembled aggregate data collected in childhood BPb surveillance systems by health departments in states and locales. We based the selection of cities for this study on availability of data and geographic distribution, making an effort to include cities in the south, the mid-west, the mid-Atlantic, and the New England regions. With the exception of Mobile, Alabama, the cities in this study are among those US cities with the highest risk for childhood lead exposure, on the basis of such features as number of children who live in poverty and in older housing. We described, by ZIP code, the number of children tested and the number of children identified with elevated BPb for the following cities:

- Detroit, Michigan, 1998 data
- Philadelphia, Pennsylvania, 1998 data
- Milwaukee, Wisconsin, 1998 data
- Mobile, Alabama, 1998 data
- Baltimore, Maryland, 1998 data
- Boston, Massachusetts, 1998 data
- St. Louis, Missouri, 1999 data

ZIP Codes

We chose to use ZIP code for our analysis because of its properties as a relatively small, homogenous, and easily recognized geographic unit. We used data from a total of 229 ZIP codes in seven cities. We excluded ZIP codes, most of which were non-residential, in which 10 or fewer children received BPb tests during the year (n=53). In cases in which a city ZIP code included addresses in an adjacent suburban area, we included the addresses that lay within the ZIP code and outside the city limits.

BPb Tests included In Our Study

We used the results of venous BPb when these were available for the year. Otherwise, we included results of capillary BPb tests in the range 10-15 µg/dL. (In some states, a BPb level in this range may not require repeat testing, so a venous BPb is not available.)

Calculating Percent of Screened Children With Elevated BPb

We calculated the percent of children with elevated BPb by dividing the number of children identified with BPb elevation by the number of children tested for the year. We performed this calculation city-wide and for each ZIP code.

Calculating Percent of Children Tested for Lead

From the 1990 US census, we extracted the number of children less than six years of age living in each ZIP code. We calculated the percent of children tested for lead for each city and ZIP code using the 1990 census figures, under an assumption of constant population and birth rate.

Results

Lead Testing Among Children

- The rates at which children were tested, city-wide, varied considerably from city to city. As might be expected, testing rates were higher in cities in which childhood lead poisoning has long been recognized as a major problem, ranging from 12% in Baltimore to 59% in Boston. In Mobile, where lead exposure to children has not historically been seen as a major public health problem, the testing rate is much lower. (See Table 1)

Table 1. Testing and identification of children with elevated BPb (≥10µg/dL), seven cities

City	Number (%) of children 0–5 years of age*	Number (%) of children 0–5 years of age tested	Percent of tested children with elevated BPb
Boston	41,528	24,332 (59%)	6.2%
Mobile	34,494	915 (3%)	11.0%
Detroit	113,215	24,691 (22%)	17.5%
St. Louis	124,349	22,691 (17%)	17.0%
Baltimore	94,930	11,506 (12%)	22.0%
Milwaukee	79,279	19,829 (25%)	26.5%
Philadelphia	138,085	31,146 (23%)	28.0%

*Data from the 1990 US Census

- There was also wide variation among ZIP codes within cities with regard to the rates at which children were tested; some ZIP codes had testing rates as much as five times that of the city-wide average.

Elevated BPb Levels Among Children

- 27,603 (19.5%) of children tested in seven cities had elevated BPb. (Note: Of the 27,603 children with elevated BPb, 1,517 either had no recorded ZIP code, or lived in a ZIP code that was excluded from our analysis. Thus, we were able to observe the distribution by ZIP code of 26,086 children with elevated BPb.)

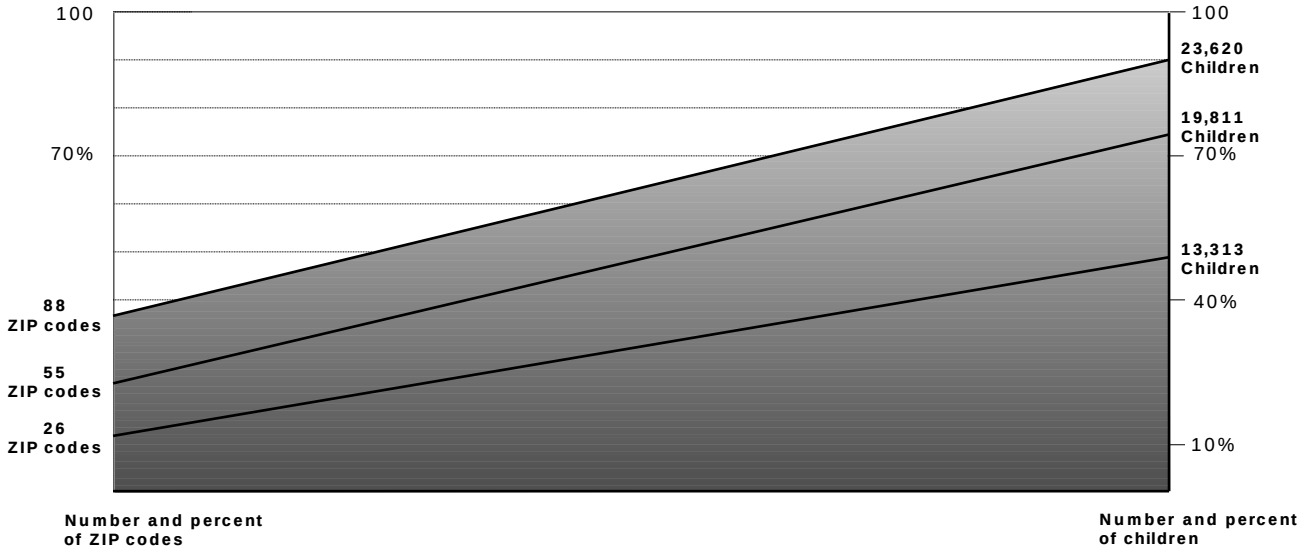
- The mean percent, city-wide, of children with elevated BPb varied from 6.2% in Boston to 28% in Philadelphia.

- The percent of children with elevated BPb by ZIP code ranged from 0 (n=11) to 47% (n=2).

Clustering of Cases

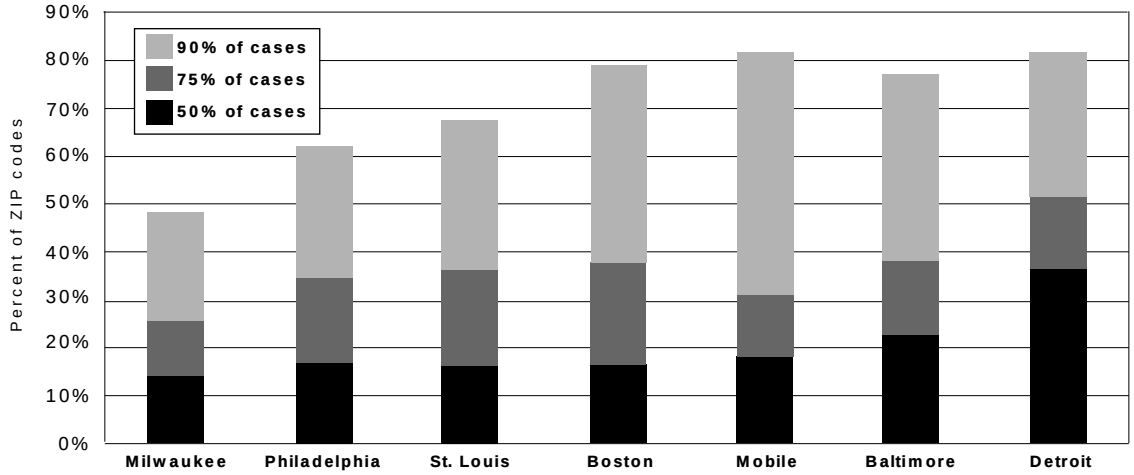
- Of the 26,086 children with elevated BPb in the 229 ZIP codes in our sample:
  - 90% lived in only 88 (38%) of the sample ZIP codes.
  - 50% lived in only 26 (11.3%) of the sample ZIP codes (See Figure 1.)

Figure 1. Number and percent of ZIP codes and number and percent of children with elevated BPb, of 26,086 children in seven cities



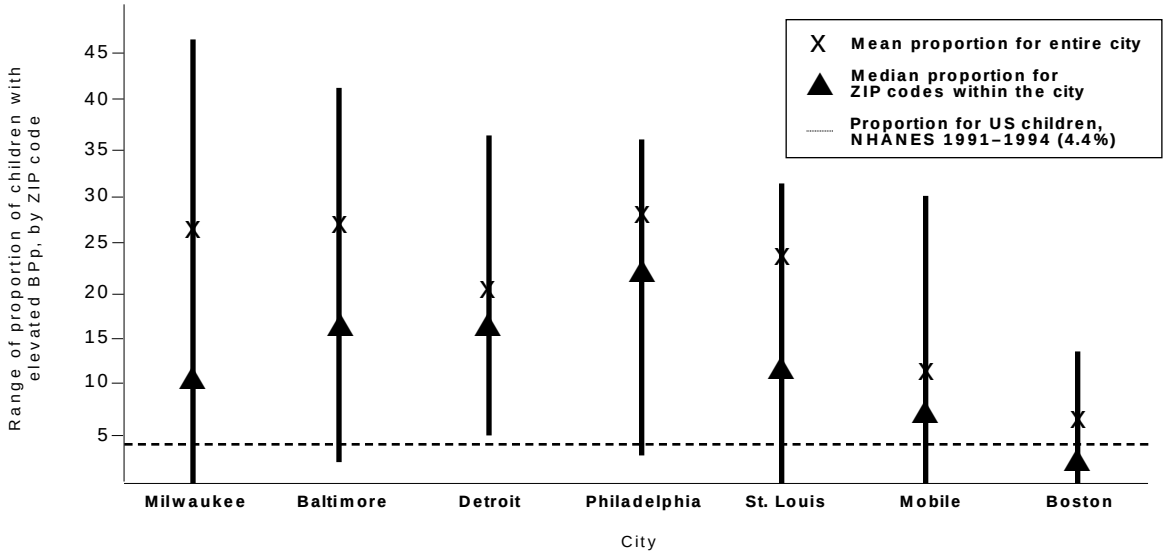
- This clustering effect held true at the city level as well; that is, in each city, most children with elevated BPb were concentrated in relatively few ZIP codes. (See Figure 2.) Conversely, in the majority of ZIP codes, the percent of children with elevated BPb is considerably lower than the city-wide average. (See Figure 3.)

Figure 2. ZIP codes* where children with elevated BPb (at least 10 µg/dL) are found: percent of ZIP codes by percent of tested children with elevated BPb levels, seven cities



*** ZIP codes with fewer than 10 children tested excluded from analyses.**

Figure 3. Comparison of mean and median proportion of children with elevated BPb, within seven cities and with the national proportion



—In Boston, Philadelphia, St. Louis, Milwaukee, and Mobile, 50% of children with elevated BPb lived in ≤ 18% of the city's ZIP codes.
—In Baltimore, 50% of children with elevated BPb lived in 24% of the city's ZIP codes.
—In Detroit, 50% of children with elevated BPb lived in 37% of the city's ZIP codes.
—In each city, the ZIP codes that were home to 50% of tested children with elevated BPb were also home to < 36% of the population 0-6 years of age, and < 45% of tested children. (See Table 2.)

Table 2. High-risk Zip Codes* and Children with Elevated BPb (≥ 10 pg/dL), seven cities

City	Mean percentage of Tested Children with Elevated BPb, City-wide	Number (%) of ZIP codes in which 50% of City's Tested Children with Elevated BPb are found	Number (%) of ZIP codes in which 75% of City's Tested Children with Elevated BPb are found	Number (%) of ZIP codes in which 90% of City's Tested Children with Elevated BPb are found
Boston	6.2%	5 (17%)	11 (38%)	18 (62%)
Mobile	11%	4 (18%)	7 (32%)	14 (64%)
Detroit	17.5%	10 (37%)	14 (52%)	22 (82%)
St. Louis	17%	10 (17%)	22 (37%)	40 (67%)
Baltimore	22%	5 (24%)	8 (38%)	16 (76%)
Milwaukee	26.5%	4 (15%)	7 (26%)	13 (48%)
Philadelphia	28%	8 (17%)	16 (35%)	29 (63%)

*ZIP codes with fewer than 10 children tested excluded from analyses.

Discussion and Recommendations

Analysis of BPb Data at the Level of ZIP Code or Smaller Unit

A striking disparity is revealed when rates of BPb elevation for tested children living in specific ZIP codes are compared to the rate for US children in general. Overall, the percentage of tested children who were identified with elevated BPb in the seven cities in our study was more than four times the estimated percentage of US children with elevated BPb from NHANES III, Phase 2. The percentage of children with BPb elevations in these seven cities was also substantially higher than that reported for 19 states in 1997-1999.[9,10]

Recommendation: In many states, data on children's BPb levels such as that used in this study are maintained in surveillance systems. Analyzing these data at the level of ZIP code or even smaller analytic unit (for example census tract or census block) should be performed in order to reveal "hot spots" where the risk for lead exposure is demonstrably high.

Targeting of Resources to High-risk Areas

It is of significance that our findings demonstrate that as few as 68 (30%) of the total sample of 229 ZIP codes included in this study were home to more than 65% of the children identified with elevated BPb. From a programmatic and policy perspective, this finding suggests that effective targeting of prevention efforts can be achieved, and underscores the possibility of eliminating childhood lead poisoning, neighborhood by neighborhood.

Recommendation: Once the data are analyzed at an appropriately small level of analysis, the results of the analysis should be used to focus resources for code enforcement, housing rehabilitation, lead hazard control, screening, and education on those areas where children have greatest risk for lead exposure.

Limitations of This Study

The Data Used in this Study are Subject to Several Important Limitations

Possibility of overestimation of rate of BPb elevations. There are several possible factors that might lead to overestimation of the rate of BPb elevations in certain ZIP codes:

- Surveillance data are likely to be the basis for overestimation of the risk for the entire population of children. State and local BPb surveillance systems are based on BPb tests performed by health care providers who have generally been encouraged (by their peers and by childhood lead poisoning prevention programs) to test high-risk children, i.e., 1- and 2-year olds who live in areas with a known high prevalence of elevated BPb or older housing.

- Capillary screening samples may also contribute to this overestimation. However, there is good evidence that, at the population level, the use of capillary specimens does not result in overestimate of the prevalence of elevated BPb.[12]

Possibility of underestimation of rate of BPb elevations. There is also the possibility of underestimation of the risk in certain other ZIP codes:

- Screening rates in many ZIP codes are very low, with the result that many children with elevated BPb may escape detection. Because the scope of this study did not include analysis of detailed data on risk factors such poverty, older housing and substandard housing conditions, we may have seriously underestimated risk for lead exposure in some ZIP codes.

- Without longitudinal data, the number of children who have ever had a BPb elevation cannot be established.

Limitations of ZIP code as a unit of analysis. ZIP codes are relatively small (average population 3,000) and most are relatively homogenous with regard to variables associated with childhood lead poisoning. Nonetheless, a ZIP code as a whole may have a low rate of childhood BPb elevation while encompassing one or more smaller neighborhoods where lead-exposed children are clustered; conversely, neighborhoods with such clusters may form parts of multiple ZIP codes. In situations such as these, ZIP code does not function well as an analytic unit. Although beyond the scope of our study, analysis using such units as census block or census tract may be preferable.

Areas for Further Study

Further study is needed to determine whether those ZIP codes in the sample of 229 with the highest rates of children with elevated BPb are more similar to each other than they are to more proximate ZIP codes with lower rates. Identification of factors common to high risk ZIP codes may allow targeting of housing remediation resources to hazardous housing, independent of screening and identification of children with elevated BPb. Such an activity would support the valuable goal of improved primary prevention of lead exposure.

Conclusion

Achieving the national health objective for 2010 of eliminating childhood lead poisoning requires focusing resources in areas with the greatest risk.[13] The data presented here are evidence of the importance of efforts to screen children at high risk for exposure and to use analyses of local BPb data to inform efforts to concentrate screening, code enforcement, housing rehabilitation, and lead hazard control in the highest risk neighborhoods. Despite the limitations of local surveillance data on which it was based, this study suggests that analyses of BPb data that are conducted at national and state levels may fail to identify highest risk areas and mask important disparities in exposure. Federal and state targeting strategies to prevent lead exposure should be—and as we demonstrate here, can be—informed and strengthened by data collected and analyzed at an appropriately small geographic level.

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