Denver Childhood Blood Lead Survey

Final Report - January 1996

Colorado Department
of Public Health
and Environment

Office of Health
Childhood Lead Poisoning
Surveillance Project

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SUMMARY

From June through September 1995, the Colorado Department of Public Health and Environment conducted a survey of blood lead levels among children living in north central Denver. The area was selected based on 1994 surveillance data; data on age of housing units, household income, and race/ethnicity; and information provided by a concerned community group. A census of a randomly selected sample of households living in the survey area was conducted from April through June 1995 to identify children from 12-35 months of age. Of the children identified in the census who could be located a few weeks later for blood specimen collection, 60.4% or 173 participated. A pediatric phlebotomist collected a blood specimen by appointment in each child's home. The proportion with blood lead levels $\geq$ 10 µg/dL was 16.2%. Five children had levels $\geq$ 20 µg/dL. While this neighborhood was clearly at at high-risk for childhood lead poisoning, no individual risk factors for having an elevated lead level were found using a questionnaire adminstered at the time the blood specimen was collected. The proportion with elevated levels was higher than expected and over five times greater than the overall rate (3.2%) for Denver County calculated from 1994 surveillance reports. The findings are consistent with the idea that there exist "pockets" of childhood lead poisoning within the city. The results of the survey highlight the problem of lead poisoning in the city and the need to provide resources for environmental investigation and intervention.

INTRODUCTION

In 1991, the Centers for Disease Control and Prevention published revised recommendations for the prevention of lead poisoning in children and recommended universal blood lead screening of young children[1]. The document did not provide specific guidance on whether or how local lead poisoning prevalence data should modify the recommendation[2]. Although the CDC also recommended that clinicians ask parents a series of screening questions, the responses to these questions were not intended to determine whether or not an individual child should have a blood lead measurement, but instead, the frequency with which the child should be tested.

Since January 1994, the Colorado Department of Public Health and Environment has operated a laboratory-based surveillance system for childhood lead poisoning. Blood lead levels $\geq$10µg/dL are required by Board of Health regulation to be reported to the state or local health department within 30 days of the finding.

Funding to support the surveillance system comes from a cooperative agreement with CDC. The award, however, does not provide for blood lead testing of children or environmental investigation and abatement or medical treatment for children with lead poisoning. During the past two years, the Department has worked with pediatricians at Denver General Hospital to assess the problem of childhood lead poisoning in the community. In addition, the State Medicaid program, with urging from community groups, has actively promoted blood lead screening for Medicaid-enrolled children and has provided funds to pay for the test and follow-up counseling to parents of children with elevated lead levels.

Blood lead surveys were conducted in small populations of Denver children in 1989 and 1990. In 1989, 617 children being treated for acute care problems in Denver Health and Hospitals clinics had blood lead meaurements: 6.5% had levels from 10.0-14.9 µg/dL and 2.5% had levels $\geq$15 µg/dL. In 1990, 124 children living in proximity to the Globeville smelter and 319 children in three other neighborhoods had blood lead measurements, and 8.4% had levels $\geq$10 µg/dL.

Surveillance data collected in 1994 demonstrated that 3.1% (144/4,675) of children ages 6 months through 6 years tested by Denver county providers had blood lead levels $\geq$10 µg/dL and 1.0% had levels $\geq$15 µg/dL. Sixty-three percent (2,931/4,675) of the children were tested in the Denver Health and Hospitals (DHH) system, and 3.0% (87/2,931) of the DHH children had lead levels $\geq$10 µg/dL, compared to 3.3% (57/1,744) of the children tested by other Denver providers. The results for non-DHH children must be interpreted cautiously because the data are attributed to Denver county based on the location of the provider, rather than the county of residence of the child, which was not obtained for children with lead levels <10 µg/dl.

The net result of the past Denver surveys and the surveillance data was that many clinicians and public health practitioners concluded childhood lead poisoning was not a significant enough problem to necessitate universal screening or to specially reserve government resources for environmental intervention and abatement for children with lead poisoning.

In 1994, staff of the Department, along with Dr. Ben Gitterman of Denver General Hospital, met several times with a concerned community group to present and discuss surveillance data on the occurrence of childhood lead poisoning in Denver. The consensus of the group was that the overall rate of childhood lead poisoning in Denver was low, but there were probably "pockets" or neighborhoods where lead poisoning was a problem. The group agreed to design and conduct a door-to-door survey of inner-city children to test this hypothesis.

Funding for the 1995 Denver Childhood Blood Lead Survey was obtained from two sources: (a) the CDC Center for Environmental Health, Lead Poisoning Prevention Branch, which supplemented the existing surveillance cooperative agreement to pay for phlebotomists and blood lead tests and (b) the Environmental Protection Agency, which awarded grant funds to the Environmental Integration Group of the Department to support a multi-disciplinary lead hazard reduction effort in Colorado. The EPA grant is designed to formulate a lead hazard reduction strategy and program for the state.

HEALTH EFFECTS OF LEAD AND CHILDRENS' EXPOSURE TO LEAD

[Abstracted from Preventing Lead Poisoning in Young Children,
A Statement by the Centers for Disease Control -- October 1991]

Lead is a poison that affects virtually every system in the body. It is particularly harmful to the developing brain and nervous system of fetuses and young children...Very severe lead exposure in children (blood lead levels ≥80 µg/dL) can cause coma, convulsions, and even death. Lower levels cause adverse effects on the central nervous system, kidney, and hematopoietic system. The blood lead level considered to indicate lead poisoning has fallen steadily since the 1970s...Although the effects of low-level lead exposure may not seem severe in the individual child, on a population basis they are extremely important...Blood lead levels as low as 10 µg/dL, which do not cause distinctive symptoms, are associated with decreased intelligence and impaired neurobehavioral development. Many other effects begin at these low blood lead levels, including decreased stature or growth, decreased hearing acuity, and decreased ability to maintain a steady posture.

Children are more exposed to lead than older groups because their normal hand-to-mouth activities may introduce many nonfood items into their gastrointestinal tract...[and] they absorb more lead than adults...Deficiencies in iron, calcium, protein, and zinc are related to increased blood lead levels and perhaps increased vulnerability to the adverse effects of lead.

Although all children are at risk for lead toxicity, poor and minority children are disproportionately affected. Lead exposure is at once a by-product of poverty and a contributor to the cycle that perpetuates and deepens the state of being poor. Substantial progress has been made in reducing blood lead levels in U.S. children. Perhaps the most important advance has been the virtual elimination of lead from gasoline...Levels of lead in food have also declined significantly, as a result of both of the decreased use of lead solder in cans and the decreased air lead levels.

Sources and pathways of lead exposure in children include: lead-based paint; soil and dust; drinking water; parental occupations and hobbies; air; food; and for some children, other source and pathways, such as "traditional" medicines may be critical. Lead-based paint remains the major source of high-dose lead poisoning in the United States. Although the Consumer Products Safety Commission limited the lead content of new residential paint starting in 1978, millions of houses still contain old leaded paint. The Department of Housing and Urban Development estimates that about 3.8 million homes with young children living in them have either nonintact lead-based paint or high levels of lead in dust...About 74% of privately-owned, occupied housing units in the United States built before 1980 contain lead-based paint. Children are exposed to lead when they ingest chips of lead-based paint or ingest paint-contaminated dust and soil.

Children with blood lead levels between 10 µg/dL and 19 µg/dL and their siblings need followup and repeat screening...They do not, however, need medical evaluation...All children with confirmed venous blood lead levels $\geq$20 µg/dL require medical evaluation...The most important factor in case management is to reduce the child's exposure to lead.

Although available evidence is not sufficient to conclude that lead-associated deficits are irreversible, a recent follow-up study reported that the educational success of a cohort of young adults was significantly inversely associated with the amount of lead in teeth they shed as first and second graders. In this study, dentine lead levels above 20 ppm were associated with a seven-fold risk of not graduating from high school, a six-fold risk of having a reading disability, deficits in vocabulary, problems with attention and fine motor coordination, greater absenteeism, and lower class ranking. Although dentine lead levels did not correspond in any simple way to blood lead levels, the available preschool blood lead levels of the more highly exposed children averaged 35 µg/dL.

Questions are frequently raised about the practical significance of the difference frequently observed between the IQ scores of more exposed and less exposed children...a shift in mean IQ score of 4-6 points as a result of lead exposure was associated with a substantial increase in the prevalence of children with severe deficits (that is, IQ scores less than 80). Similarly, in this population the shift was associated with an absence of children who achieved superior function (that is, IQ scores greater than 125).

METHODS

A. Neighborhood Selection

The neighborhoods chosen for inclusion in the 1995 Denver Childhood Blood Lead Survey were selected based on several sources of information:

1. Public health surveillance data for 1994 were used to identify areas in Denver where children with elevated blood lead levels lived;
2. A community group, knowledgeable about childhood lead poisoning, identified neighborhoods which they thought had relatively large numbers of children at high risk for lead poisoning who had not been offered blood lead screening;
3. 1990 Census data were used to identify tracts with old housing units, a high proportion of households with incomes below the poverty level, and a high percentage of minority persons.

The neighborhoods selected were bounded by 40th Ave. on the north, 16th Ave. on the south, Milwaukee St. on the east, Park Ave. and 23rd St. on the southwest, and Broadway and Walnut St. on the west and northwest--this area is north and east of the central downtown region of the city. A map of the survey area is included in attachment 1. In 1994, a total of 30 children were reported with blood lead levels >10µg/dl in this area. The neighborhoods included the surveillance areas with the greatest clustering of children with elevated blood lead levels, and also included the neighborhoods of concern to the community group.

The selected neighborhoods consisted of nine census tracts. In these census tracts, household incomes below the poverty level ranged from 27% to 53% of the population, and eight of nine census tracts had >30% of the households living below the poverty level. All census tracts were comprised of at least 50% of minority persons, and seven of nine tracts had >75% of their population comprised minority persons. Seven of the nine census tracts had at least 47% of the houses built before 1940. In four census tracts, >50% of the houses were constructed prior to 1940, >20% of households had incomes below the poverty level, and >60% of the population were minority persons.

B. Neighborhood Census

We conducted a census of children in the neighborhood so that we could compare blood lead survey participants to non-participants and evaluate whether the participants were representative of all children in the neighborhood. The sample size of the survey was determined by funding which was sufficient for 250 participants. From the 1990 census data, the number of 12-35 month old children in the survey area was estimated. The participation rate was estimated to be 50%-70%. Based on this, it was determined

that half of the survey area was needed to generate adequate numbers of participants. A random sample of 186 blocks was selected in a checkerboard fashion within the boundaries of the survey area. Several blocks which contained no housing units or were entirely composed of public housing units were excluded. A sequential block number was assigned to each block and the street boundaries defining the block were mapped on individual block survey forms (see attachment 2) for each of the 186 blocks.

Twelve community workers, of whom two were Spanish-speaking, were hired to complete the census. A training session was held prior to the onset of the survey which included an orientation outlining the purpose of the survey, general lead information, and instructions on how to complete the block survey form and the census form (attachment 3). Also discussed were proper verbal etiquette, potentially difficult situations, and administrative details such as scheduling and filling out time sheets. Block assignments were made to each census worker at the conclusion of the training session. The census was conducted from April through June 1995.

One census form was completed for each household. Information collected included the name of informant, the name, sex, and birth date of each household resident <3 years, and the best time of day to recontact. If an adult or older child was at home, the census worker completed the form. If no one was home or no one was able to give census information, a letter was left which explained the survey and also gave household members the option of calling in with the census information.

The number of attempts to contact the residents of a house and the completion status of the household census were recorded. If the census worker could not find anyone home after four visits at different times of the day and census information could not be obtained, the completion status of the census form was noted as "no contact made", and no further attempts to contact the residents were made. Refusal to participate in the census and the need for a Spanish speaking worker were also recorded. Completed census forms were reviewed for accuracy, and residents were recontacted if necessary.

Addresses of households participating in the census were submitted to the City and County of Denver Assessment Division, which then provided the date of construction of the residence.

C. **Blood collection and questionnaire administration**

A consent form for participation in the survey (i.e. blood collection and completion of a questionnaire) was drafted, reviewed, and approved by the CDPHE IRB (see attachment 4 [consent forms] and attachment 5 [questionnaire]). Both English and Spanish versions were prepared. The survey was conducted from June-September

1995. Participant selection was initiated prior to completion of the census. Census participants who lived or spent a significant amount of time in a residence constructed prior to 1978 and who were 12-35 months of age were eligible.

After reviewing census forms to identify eligible households, project staff contacted parents/guardians by telephone to obtain permission for their child/children to participate in the survey. Individuals without a telephone were visited. For those who agreed to participate, an appointment for a home visit was scheduled. At the home visit, the community worker obtained written consent from the participant's parent/guardian, adminstered the questionnaire, and assisted the phlebotomist and parent with the blood specimen collection from the child.

Six pediatric phlebotomists were hired. The phlebotomists drew only venous samples and were instructed to make no more than two attempts. They wiped the skin with alcohol and used 23 gauge butterfly needles. The phlebotomists drew a minimum of 1.75 mL of blood into each 3mL lavender-top vacutainer tube.

Blood specimens were delivered daily to Corning Clinical Laboratories for analysis. The specimens were analyzed for lead only. Corning Clinical Laboratories participates in the CDC blood lead proficiency testing program for laboratories, is certified by Occupational Safety and Health Administration (OSHA), accredited by the College of American Pathologists, and meets Clinical Laboratory Improvement Amendments (CLIA) requirements. Their analytical technique for blood lead had a determination limit of 1 µg/dL using atomic absorption spectrometry.

The questionnaire consisted of 39 questions concerning:

- personal characteristics--age, gender, race/ethnicity, educational level of parent/guardian, household income
- the child's residence--owner, construction date, plumbing, number of persons in, peeling or chipping paint
- health care--Medicaid, Denver public clinic, previous tests for or diagnosis of lead poisoning, treatment of other household members for lead poisoning,
- risk for lead exposure--occupational or hobby exposure by adult resident, use of home or folk remedies, paint removal.

D. **Participant notification and follow-up**

The parent/guardian for each child participant was sent a letter (attachment 6) listing each child's blood lead level and date of test, the normal range for blood lead levels, and for those children with elevated results, recommendations for follow-up were provided.

Parents/guardians of children with blood lead levels ≥ 10 µg/dL were notified by telephone in addition to the letter. Potential sources of exposure and needed follow-up were discussed. The participant's health care provider was also sent a notification letter (Attachment 7) informing them of their patient's elevated lead level and test date.

Participants with blood lead levels ≥20 µg/dL were offered a home visit by environmentalists to discuss and identify potential sources of lead. A questionnaire containing 68 questions guided the discussion and gave the parents additional information on possible sources of lead exposure. Lead check swabs were also used to test some painted surfaces (walls, floors, pottery, etc.) in and around the home for lead content.

E. **Data management and analysis**

Information from the neighborhood census was entered into a data file using dBASE III+. The data were double-entered, and the two files compared. When discrepancies were identified, the hardcopy of the original census form was examined. The total number of data entries into both files was 6,336; 57 errors were identifed (a rate of 0.9%). The questionnaire data and blood lead test results for survey participants were entered into a separate data management file using Foxpro. These data also were double-entered; when discrepancies between the two files were identifed, they were compared to the hardcopy questionnaire form.

The census, questionnaire, and blood lead level data files were analyzed using SAS (ver 6.03). Survey participants were compared to non-participants to assess representativeness of the sample. Among survey participants, children with elevated blood lead levels were compared to children with non-elevated levels. An elevated blood lead level was defined as ≥10 µg/dL. For continuous variables, the student's t test and analysis of variance were used; for categorical variables, chi square contingency table and/or Fisher's exact tests were used. A p value <0.05 was considered statistically significant.

RESULTS

A. Neighborhood Census and Survey Participants

4,167 households were screened, and a total of 352 children were determined to be eligible to have a blood specimen collected and questionnaire administered. Of the eligible children, a total of 173 individuals ultimately participated in the survey, as shown in Table 1 below. A map indicating the location of the participants (closed circles) and the eligible children who refused to participate (open circles) is attachment 8.

The 173 participants resided in 118 separate houses: there was 1 participant in 97 households; 2 participants in 18 households, 3 participants in 2 households, and 4 participants in 1 household. Eleven participants were <12 months of age and 18 participants were between 36 and 47 months of age; these children were included because (a) their age was <36 months at the time of the census but was ≥36 months by the time of the survey; (b) the age provided at the time of the census was subsequently found to be incorrect; or (c) parental consent for 12-35 month old children would not be given unless older or younger siblings were also tested.

Table 1. Survey enrollment status of eligible children identified by the neighborhood census (N=352)

Participated in blood lead/questionnaire survey	173	49.1	%
Refused to participate	107	30.4	
Moved between date of census and date of survey	66	18.8	
Agreed to participate but unable to obtain blood specimen	6	1.7	

After excluding children who could not be located at the time of the survey, the overall participation rate was 173/286 = 60.4%. In Table 2, selected characteristics of survey participants are compared to non-participants. The non-participant group excludes the 66 children who moved away in the interval between the census and the survey. The data were collected during the neighborhood census and are less complete than data collected on the questionnaire. For example, in Table 2, age is respondent-reported, whereas data on age derived from the questionnaire (reported in Table 5) was calculated from the date of birth.

Table 2. Comparison of survey participants to non-participants for selected

characteristics ascertained during the neighborhood census, Denver, 1995.

	Participants (n=173)	Non-Participants (n=113)	P value
Mean age (months)	24.3 ±8.5	22.9 ±7.2	0.07
Age distribution (in months):			
6-11	6.4%	2.7%	
12-23	39.9	49.6	
24-35	43.4	43.4	
36-47	10.4	4.4	0.09
% male	50.3	50.0	NS
Home construction date:			
1880-1919	67.6 %	58.4 %	
1920-1939	9.3	14.2	
1940-1959	6.9	9.7	
1960-1978	6.9	7.1	>0.5 [2x5 table, collapsing the 1979-1995 cells into the 1960-1978 cells]
1979-1995	0.0	0.9	
Unknown	9.3	9.7	

More detailed information about the survey participants was obtained from the questionnaire. The mean age of participants was 24.9 ± 8.4 months, and the median was 24 months. 51.4% were male; 63.6% were Hispanic and 28.3% were Black. The children had lived a median of 12 months in the residence. 57.8% had never previously had a blood lead level measured. The mean number of persons living in the household was 5.2 ± 2.3 (median 4, range 2-18). The median number of years of school completed by the parent/guardian of the child was 10. The Table below presents additional information reported by survey participants to the community workers. The responses were not independently verified. Fifty-two percent (n=90) of the respondents reported they did not take their child to a Denver public health clinic for medical care; of these, 42 did not provide the name of either a clinic or physician who delivered care to their child.

Table 3. Questionnaire responses by Denver lead survey participants (n=173).

	% Yes	%No	%Don't know

●Is this residence owned by the Denver Housing Authority?	10.4	84.4	5.2
●Has the paint in this residence ever been removed during remodeling because it contained lead?	6.4	47.4	46.2
●Has your child's blood been tested for lead within the last 3 months?	3.5	96.0	0.6
●Has a nurse or doctor ever told you that someone in your home has a problem with lead in his blood?	2.9	96.5	0.6
●Do you take your child to a Denver public health clinic for his medical care?	45.1	52.0	2.9
●Is your child on Medicaid?	57.8	39.3	2.9
●Does your child have a sibling, housemate, or playmate being treated or followed for lead poisoning?	1.7	96.5	1.7
●Does your child live in a home with plumbing which has lead pipes or copper with lead solder joints?	29.5	30.1	40.5
●Does your child live with an adult or have contact with an adult who works with lead?	26.6	71.7	1.7
●Does your child take any home or folk remedies which may contain lead?	8.7	89.0	2.3

B. **Blood lead levels and risk factors for having an elevated lead level**

The blood lead levels were categorized into five groups, and the distribution is shown in Table 4 below. Overall, 28 (16.2%) of the 173 tested children had levels $\geq$10 µg/dL. The arithmetic mean value was 7.0 µg/dL $\pm$ 4.7 (range 0.9-30.0), and the median level was 6.0 µg/dL. Each of the six phlebotomists had at least one of their patients with an elevated blood lead level.

Table 4. Distribution of blood lead levels in Denver lead survey participants, 1995.

Blood Pb Level (µg/dL)	Number	Percentage
<10.0	145	83.8
10.0-14.9	18	10.4
15.0-19.9	5	2.9
20.0-24.9	2	1.2
25.0-39.9	3	1.7

The majority of children with elevated levels were located north of 26th Street (24 were north, 4 were south), and the rate of elevated levels was slightly higher among children located north of 26th Street (24/143 or 16.8% vs. 4/30 or 13.3%; p >0.5). When comparing the location of children with elevated levels found in the 1995 survey with the

location of children reported to the surveillance system in 1994, it appears that the distributions are similar except that the 1995 survey identified more children with elevated lead levels living west of Downing Street (7 vs 4).

When comparing children with blood lead levels <10 µg/dL to children with levels ≥10 µg/dL , no statistically significant differences were observed. Selected findings are presented in Table 5.

Table 5. Comparison of children with elevated blood lead levels to children with normal blood lead levels measured during the neighborhood survey, June-September, 1995.

	Children with Pb ≥10µg/dL (n=28)	**Children with Pb <10µg/dL** (n=145)	**P value**
•Mean age (months)	24.1 ±7.6	25.8 ±8.9	>0.3
•% male 60.7	49.7	>0.3	
•Race/ethnicity:			
Hispanic	57.1	64.8	
Black	35.7	26.9	
White, non-Hispanic	7.1	4.8	
Other	0.0	3.5	>0.7
•Has a provider ever told you that someone in your home had a problem with lead in the blood?			
% Yes	7.1	2.1	>0.3
•Do you take your child to Denver public health clinics for care?			
% Yes	53.6	43.5	>0.4
•Is your child on Medicaid?			
% Yes	57.1	57.9	>0.3
•Household income,			
% <$25,000/year	60.7	66.2	>0.6
•Mean number of months child had lived in this residence	15.5 ± 10.6	16.2 ± 10.3	>0.7
•Mean number of persons living in the same household with the child	5.8 ± 1.8	5.1 ± 2.3	>0.15

Table 5. continued

	Children with Pb ≥10µg/dL (n=28)	**Children with Pb <10µg/dL** (n=145)	**P value**

•Home construction date:			
1882-1939	89.3	83.7	
1940-1965	7.1	8.5	
1966-1976	3.6	7.8	>0.7
•Residence owned by the Denver Housing Authority?			
% No	85.7	84.1	>0.7
•Does your child live in or regularly visit an old house, day care center, preschool, or home of a babysitter that was built before 1960 and has chipping paint?			
% Yes	39.3	33.3	>0.5
•Does your child live in a home with plumbing which has lead pipes or copper with lead solder joints?			
% Yes	28.6	29.7	>0.9
•Does your child live with an adult or have contact with an adult who works with lead?			
% Yes	21.4	27.6	>0.5
•Does your child take any home or folk remedies which may contain lead?			
% Yes	7.1	9.0	>0.8
•How many times since birth has your child had his blood tested for lead?			
% reporting zero	53.6	58.6	>0.6

C. **Follow-up of children with an elevated blood lead level**

Parents/guardians of children with elevated blood lead levels and the health care providers of these children were given CDC recommendations for follow-up testing and care[3]. Follow-up testing data were located for three of five children with lead levels $\geq$ 20 µg/dL: patient A tested two months after initial level of 29 had a measurement of 15 µg/dl (after chelation therapy); patient B tested 11 days after an initial level of 30 had a measurement of 26 µg/dL; patient C tested two months after an initial level of 23 had a measurement of 15 µg/dL. Follow-up testing data were located for three of five children with lead levels in the range 15.0-19.9 µg/dL: patient D had an initial level of 15 and two weeks later had a measurement of 21µg/dL; patient E had an initial level of 15 µg/dL and one week later had a measurement of 3 µg/dL; patient F had an initial level of 16 µg/dL and a follow-up measurement (exact date unknown) of 11 µg/dL.

Environmental investigation of the five children with lead levels >20 µg/dL revealed that lead-based paint was the most likely source of lead for four of the five children. For the fifth child, the father's household hobby of working with stained glass was a probable source of lead. One family has already relocated, and two others are trying to find

suitable, safe housing. One mother transfered her child to relatives living in safer housing. Another home owner has repainted his home's exterior since learning of the child's elevated blood lead level.

DISCUSSION AND COMMENT

The 1995 survey found a much greater rate (16.2%) of children with elevated blood lead levels than was expected based on 1994 surveillance data or past Denver surveys. Although the blood specimens were collected in patients' homes rather than a more controlled clinical setting, there is no evidence that the laboratory results were spurious because the laboratory was a consistent participant in the CDC lead testing proficiency program, because elevated levels were obtained by each of the six phlebotomists, and because six of seven children with elevated blood lead levels who underwent follow-up testing had elevated levels measured by their own health care provider and his/her laboratory. That the sample population is representative of children in the area is supported by the design of the survey, i.e. systematic selection of blocks distributed throughout the defined area, and census data showing no significant differences in age, gender, or home construction date between survey participants and non-participating, eligible children within the area.

The findings are consistent with the idea that there exist "pockets" of childhood lead poisoning within the city. It may be argued that the particular "pocket" of Denver that we surveyed had an "unrecognized" lead problem. However, the lack of recognition was primarily because a lead poisoning rate specific for this area had not previously been determined. A rate would permit comparison with other neighborhoods within and outside of Denver, leading to recognition of the problem in the surveyed neighborhoods. Although the surveillance data showed clustering in the area we surveyed, area-specific denominator data were not available. The problems specific to this "pocket" of the city were, thus, masked by the overall low rate of lead poisoning reported for the entire city of Denver.

We think neighborhoods with high potential for having children with lead poisoning can be identified without special surveys if there are sufficient surveillance data (i.e., more than a few cases) that demonstrate clustering of reported cases in the "pocket" and if housing data show the area to contain old homes belonging to impoverished families which do not easily access medical care. While high-risk neighborhoods can be identified, we were not able to identify high-risk individuals, i.e. specific risk factors associated with having an elevated blood lead level. One possibility is that this was due to the small sample size: retrospectively, the calculated statistical power ranged from 15% to 35% (to detect an odds ratio of 1.5-2.0 with exposure rates in the comparison group from 5% to 50%). However, data in Table 5 show no large differences between children with elevated and non-elevated blood lead levels (except for the 3.4-fold difference--7.1% vs 2.1%--in parents/guardians having been told that someone in the family had a problem with blood lead levels) that might have been statistically significant if the survey population size had been larger. Our ability to identify risk factors associated with having an elevated blood lead level would be improved with neighborhood-specific information about the sources of lead exposure.

With that information, the questionnaire could be designed to ask more culturally- and community-specific behavioral questions, as was done in Santa Clara County, California and recently reported[4].

Although we found less than 60% of the surveyed children were on Medicaid and less than 50% attended public clinics, and less than 40% had household incomes greater than $25,000/year, these statistics do not portray a clear picture of whether and how the families obtain ongoing health care. In high-risk neighborhoods, extraordinary efforts, i.e. active outreach, appear to be necessary to engage and educate families about childhood lead poisoning and its recognition and treatment. We suspect the families may also need more preventive health care in general, including routine well-child care, injury prevention, and immunizations. Nonetheless, it would be unfortunate if the over-reaching problems of poverty and the general need for primary health care created inertia such that a specific preventable disease, i.e. lead poisoning, was not addressed.

Physicians are trained not to order a diagnostic test unless the physician is prepared to act on the results. As for childhood lead poisoning, it would be preferable to assure adequate resources for environmental investigation and abatement prior to testing children. Although medical care through Denver Health and Hospitals was available to each child identified by our survey as having an elevated blood lead level and limited resources for environmental intervention exist through CDPHE and the Denver Department of Public Health, environmental intervention is not usually straightforward and inexpensive, and it requires clear statutory authority. We hope that one contribution made by the survey is to bring attention to the problem of lead poisoning in the city and to cause discussion about the provision of environmental resources necessary to protect Denver's children.

Recommendations

1. Efforts should be made by both the State and the City and County of Denver to obtain resources for environmental investigation and intervention of childhood lead poisoning.
2. State and local health departments should identify neighborhoods with high potential for having children with lead poisoning using surveillance data (i.e., clustering of reported cases in one area) and housing and census data.
3. Denver Health and Hospitals (as the lead agency), the State, and other health care providers should promote primary health care services, including lead screening, for young children in the survey neighborhood.

ACKNOWLEDGEMENTS

This survey was supported in part by a cooperative agreement from the Centers for Disease Control and Prevention, award H64/CCH809719, and the TSCA Title IV cooperative agreement with the Environmental Protection Agency.

REFERENCES

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2. Ibid.

3. Ibid, pp 43-47.

4. Snyder DC, Mohle-Boetani JC, Palla B, and Fenstersheib M. Development of a population-specific risk assessment to predict elevated blood lead levels in Santa Clara County, California. Pediatrics 1995;96:643-48.