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Is Home Renovation or Repair a Risk Factor for Exposure to Lead Among Children Residing in New York City?

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ABSTRACT *Children can be lead poisoned when leaded paint is disturbed during home renovation or repair. We conducted a case-control study to assess the association between elevated blood lead levels (BLLs) in children younger than 5 years of age and renovation or repair of homes built before 1950 in New York City. In 1998, we interviewed parents of 106 case children (BLLs ≥ 10 μg/dL) and 159 control children (BLLs ≤ 5 μg/dL) living in selected New York City neighborhoods. We then used logistic regression methods to estimate odds ratios (ORs) for elevated BLLs among children living in housing that had undergone various renovations or repairs in the 6 months before the blood lead test, and we adjusted for age and test month. Case children were only slightly more likely than control children to live in a house that had undergone any renovation (OR = 1.2, 95% confidence interval [95% CI] = 0.7, 2.1). Case children were more likely to (1) live in housing that had interior surfaces prepared for painting, especially by hand sanding (OR = 3.5, 95% CI = 1.1, 10.9; population attributable risk [PAR%] = 10.4%, 95% CI = 0.5%, 19.3%); and (2) have work-created dust throughout their housing unit (OR = 6.3, 95% CI = 1.2, 32.3; PAR% = 6.8%, 95% CI = 0.0%, 13.1%). The risk for excess lead exposure is increased by home renovation or repair work involving interior paint preparation or reported dispersal of dust beyond the work area. The proportion of cases related to this exposure is high enough to merit preventive measures.*

KEYWORDS *Children, Home renovation, Home repair, Lead poisoning.*

INTRODUCTION

Although blood lead levels (BLLs) among children in the United States have dramatically declined in association with the elimination of leaded gasoline, lead paint, and lead-soldered food cans, as well as ongoing blood lead screening and health education, approximately 900,000 US children are estimated to have BLLs high enough to adversely affect cognitive performance and behavior.[1–4] The remaining childhood lead exposure problem has been linked mainly with exposure to leaded paint in older housing.[4] According to the Third National Health and Nutrition

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Examination Survey (NHANES III), the risk for an elevated BLL among children living in older (pre-1946) dwellings, built when the use of lead pigment paints was widespread, is approximately five times that among children living in homes built after 1973, most of which were built after leaded house paint was banned in 1978.[5]

Exposure to house dust contaminated with lead from deteriorating lead-based paint is considered the most important pathway of exposure to lead for children in the United States.[6–8] Young children ingest the contaminated dust by placing their fingers, toys, and other objects into their mouths. There are 26 million families who live in homes built before 1950, when lead-based house paint commonly contained up to 50% lead by weight.[9]

Contamination of house dust can occur when leaded paint deteriorates; hence, children from low-income families who live in older housing are at especially high risk.[4,5] Proper home maintenance can help prevent such deterioration, but case reports have shown that some children are poisoned by renovation or repair work.[10–12] The New York City Department of Health (NYCDOH) Lead Poisoning Prevention Program noted that 25% (2,250/9,000) of records of children with elevated BLLs in 1997 reported some type of home renovation activity (J. Leighton, personal communication and unpublished data, 1998). Case investigations of all children with lead poisoning over a 2-year period (1993–1994) in New York State noted recent home renovation in 7% of these health department records.[13] Such case series, however, do not provide estimates of the relative or population-attributable risk of lead poisoning from home renovation or repair. The only study to use a control group and standardized methods to assess home renovation was commissioned by the Environmental Protection Agency (EPA) in Wisconsin.[14] Therefore, we conducted a retrospective case-control study to estimate the relative and attributable risks due to home renovation or repair activities of elevated BLLs among children living in New York City buildings constructed before 1950.

METHODS

Study Population

To draw our study population from neighborhoods in which renovation might have its strongest relation to lead poisoning, we studied middle-to-high-income neighborhoods with housing that should be relatively well maintained and have a high proportion of older housing, in which leaded paint is commonly found. Thus, to select children for study, we used census data (1990 US Census, tape ST3A) to identify ZIP codes with a relatively high percentage of homes built prior to 1950 (average 68% in selected ZIP codes vs. 39% in those not selected), higher percentage of homes owner occupied (average 39% in selected ZIP codes vs. 28% in those not selected), and higher median household income (average $34,987 in selected ZIP codes vs. $28,875 in those not selected). Separate z scores were assigned to each ZIP code for each of these factors, and a composite score was computed from the sum of the three scores, weighting the housing score by a factor of 3. All ZIP codes were rank ordered according to this composite score, and the highest-ranking ZIP codes were chosen in order until projected sample size requirements were met. The selected areas represent 82 of 158 ZIP codes in which children under 6 years of age lived. In 1990, the selected (target) ZIP codes housed 43% (233,349/548,685) of New York City children younger than 6 years old.

To be eligible for the study, children had to be 6 to 60 months of age and, to avoid interlaboratory variability, had to have their blood tested at the NYCDOH Public Health Laboratory from June 1 through September 30, 1998. These dates were selected to capture the seasonal peak of elevated BLLs.[6] Other criteria included residence in housing constructed before 1950 (based on a city property tax database), presence of a telephone number on laboratory requisition slips, and no prior history of elevated blood lead measurements as determined from the blood lead registry. New York State law requires lead exposure screening of children at both 1 and 2 years of age and annually up to age 6 years if children remain at risk for lead exposure. Among the children born in New York City in 1996, approximately 81% were tested for lead exposure at least once by 36 months of age (J. Leighton, personal communication and unpublished data, 1998). Blood lead data were obtained from the blood lead registry maintained by the NYCDOH Childhood Lead Poisoning Prevention Program, which receives reports of all tests performed on residents of New York City. According to the blood lead registry, the NYCDOH Public Health Laboratory tested 24% (3,796/15,706) of the lead-screened children younger than 6 years of age who resided within the target ZIP codes. Among children younger than 6 years of age living in the target ZIP codes, those whose blood lead was measured at the NYCDOH laboratory had a somewhat higher mean BLL (5.2 μg/dL) than those who had their blood tested at other laboratories (4.7 μg/dL, $P < .001$ for difference in means).

We attempted to enroll as cases all children meeting the eligibility criteria who had blood lead measurements of 10 μg/dL or higher. We attempted to enroll as controls a sample of children with BLLs of 5 μg/dL or lower, frequency matched to cases at a 2 : 1 ratio based on the case child's date of birth (within 6 months) and the date their blood was tested for lead (within 3 months). Using 7% as the estimated background rate of exposure to renovation and remodeling in the target New York City ZIP codes,[13] we attempted to enroll 106 children as cases and 212 children as controls to be able to detect an odds ratio of 3.0 with 80% power and 95% confidence.

Data Collection

Parents or guardians of case children and control children were interviewed in English or Spanish by telephone within 45 days of their child's most recent blood lead test date (interviewed from June 1 through November 15, 1998) after informed consent was obtained. They were asked about specific types of home renovations and repairs throughout the 6 months before their child's blood lead test. They were also surveyed about the amount of dust and debris generated, methods of clean up, and who performed the work and cleanup. The interviewers were blind with respect to case or control status. Institutional review boards of both the NYCDOH and the Centers for Disease Control and Prevention (CDC) approved the protocol.

Statistical Methods

We performed crude bivariate analyses of types of renovation work, dustiness, type of worker, and work practices utilizing case status as the outcome. For exposure measures significantly associated with case status in bivariate analyses, multivariate unconditional logistic regression models were developed to adjust for potential confounders. In addition, the models included variables used to frequency match the control group to the case group (age and test date). For the regression models, missing demographic data values were recoded into the most prevalent response category for each variable to enable further analysis. In addition, because there were only small numbers of white children and children missing race data, they were all grouped within the "other" race category for regression analysis. In the regression analyses, the referent category for each renovation activity included all for whom the activity was not reported, including blank and "don't know" responses. We included the blank and don't know responses since they were low in percentage, ranging from 0% to 3% for the exposure factors examined. We assumed that significant renovation or repair work would have been known to respondents, who had lived in the dwelling at least as long as the period covered by the interview. To the extent that some misclassification resulted from this grouping, it would tend to bias our results toward the null hypothesis, thereby making it more difficult to detect a significant difference (more conservative). The population-attributable risk percentage (PAR%) was estimated for exposure variables that were significant predictors of case status in multivariate models.[15]

RESULTS

The overall participation rate was somewhat, although not significantly ($P = .17$), better for case children (54%) than for control children (48%). Phone complications were the most common reason for failing to enroll an eligible participant (25% of eligible records). Phone complications included wrong information (52% of those not reached), language barrier (19%), and disconnected lines (17%). Parents/guardians of a similar proportion of eligible case children and control children declined participation. Subsequently, three case children and six control children were excluded from analysis based on incomplete interviews, leaving a final study group of 106 case children and 159 control children. Based on data available in the blood lead registry, enrolled case children and control children did not differ significantly from nonparticipant cases and controls with respect to known sex, age, and BLLs (Table 1); however, a significantly greater percentage of nonparticipating control children were missing sex information in the registry.

The final study group of case children did not differ substantially or significantly from control children with respect to age, year their residence was built, sex, or social factors (Table 2). There was a greater percentage of white children in the control group than in the case group, which was statistically significant; otherwise,

TABLE 1. Characteristics of eligible children: nonparticipants compared with enrollees

	Nonparticipant cases (n = 92)	Enrolled cases (n = 109)	Nonparticipant controls (n = 176)	Enrolled controls (n = 165)
Sex: female, %	62	54	61	56
Sex: unknown, %	17	12	24*	17*
Age,† months	28 ± 16	29 ± 16	30 ± 16	29 ± 17
Blood lead level,† μg/dL	14 ± 5	14 ± 4	3 ± 1	3 ± 1

Source: New York City Department of Health, Childhood Lead Poisoning Prevention Program Blood Lead Registry.

*Statistically significant difference in proportion of unknown sex among nonparticipating and enrolled controls.

†Reported as arithmetic mean ± standard deviation.

TABLE 2. Characteristics of final study group

Demographic variables	Cases (n = 106)	Controls (n = 159)
Blood lead level (BLL),* µg/dL	14 ± 4 (10 – 30)	3 ± 1 (1 – 5)
Age,* months	29 ± 16	29 ± 17
Year residence built*	1923 ± 11	1924 ± 11
Sex, % males	56	52
Race, %		
White	3†	9†
Black	48	46
Hispanic	10	15
Asian	13	12
Other	25	17
Total household income $30,000 or less, %	72	74
Education of respondent high school or less, %	66	61
Single parent, %	26	30

Source: Research questionnaire.

*Reported as average ± standard deviation.

†Statistically significant difference in percentage of white children among case children and control children in the final study group.

the distribution of race/ethnicity did not differ significantly. Only 1% of the respondents did not provide data on race, total household income, and number of parents living with the child; while 2% did not answer about education level of the parent answering the questionnaire. Nearly three quarters of respondents reported household income less then $30,000 per year, substantially lower than the median household income (based on 1990 data) in the ZIP codes from which they were drawn.

Renovation and Repair Activity

Approximately one third of the respondents (37% among case children; 32% among control children) reported at least some renovation or repair activity during the 6 months before the index blood lead test (Table 3). The referent category used for estimating ORs for each activity was all for whom the activity was not reported,

TABLE 3. Relation between home renovation or repair activities and case status

Renovation or repair activities*	Case (N = 106), %	Control (N = 159), %	Crude odds ratio	95% Confidence interval
Any event	37	32	1.2	0.7–2.1
Breakage of interior wall	26	22	1.2	0.7–2.3
Interior paint preparation	19	10	2.2	1.0–4.9
Exterior repair	10	10	0.9	0.4–2.3
Exterior paint preparation	9	10	0.9	0.3–2.3

*The referent category for each activity was all for whom the activity was not reported, including blank and don't know responses.

including blank and don't know responses. Both case children and control children had 0%–3% of responses missing for each category of work performed. A report of any renovation work had a weak and nonsignificant association with case status (OR = 1.2, 95% confidence interval [95% CI] = 0.7, 2.1).

Interior Paint Preparation Methods

Among types of renovation work performed, interior paint preparation, but not other types of work, was associated with case status (OR = 2.2, 95% CI = 1.0, 4.9). We therefore evaluated the association between case status and specific paint preparation methods reported with sufficient frequency for further analysis: scraping and sanding. Among these two paint preparation methods, hand sanding was associated with an increased risk for elevated BLLs (OR = 3.5, 95% CI = 1.1, 10.9) compared with "no preparation" as the referent category and adjusting for age and test month using logistic regression (Table 4). Paint preparation that did not involve hand sanding had a nonsignificant association with elevated BLLs (OR = 1.5, 95% CI = 0.6, 3.9). A statistically significant linear trend in odds ratios was detected (P = .03) when paint preparation methods were considered as one three-level ordinal variable (no preparation, preparation by another method than sanding, preparation by sanding), with the ranking determined by the amount of lead-contaminated dust produced by each category of preparation. Further adjustment for other covariates such as sex, race, test method, year of housing construction, pica behavior, mouthing behavior, initial paint condition, and social factors did not alter the odds ratios shown in Table 4 by more than 3% in either direction, with the exception of pica behavior, which reduced the odds ratio by 20% (OR = 2.8).

Dust and Debris

The extent of visible dust and debris reported was associated with the risk of elevated BLLs (Table 5). If no visible dust and debris were reported or dust and debris were limited to the work area, the risk of elevated BLLs was similar to that for children with no reported renovation or remodeling work (OR = 0.8, 95% CI = 0.4, 1.5). Renovation and remodeling work that resulted in visible dust or debris throughout the home was strongly associated with elevated BLLs (OR = 6.3, 95% CI = 1.2, 32.3), adjusted for age and month of test. Further adjustment for other covariates, as mentioned above, did not alter the odds ratios shown in Table 5 by more than 6% in either direction, with the exception of respondent's education (either parent) and pica behavior, which both reduced the odds ratio by 16% (OR = 5.3).

In summary, the largest effects were for preparing an interior surface for paint-

TABLE 4. Relation between interior paint preparation method and case status

Categories	Cases (N = 106), %	Controls (N = 159), %	Adjusted odds ratio (95% confidence interval)*
No preparation	81	90	1.0 referent
Preparation method other than by hand sanding†	9	7	1.5 (0.6–3.9)
Preparation by hand sanding	9	3	3.5 (1.1–10.9)

*Adjusted for age and month of test.
†This category includes the don't know or missing responses.

TABLE 5. Relation between the extent of visible dust within the home and case status

Categories	Cases (n = 106), %	Controls (n = 159), %	Adjusted odds ratio* (95% confidence interval)
No interior work	72	75	1.0 referent
No dust or only near work area	22	24	0.8 (0.4–1.5)
Dust everywhere	7	1	6.3 (1.2–32.3)

*Adjusted for age and month of test.

ing, with an estimated PAR% of 10.4% (95% CI = 0.5%, 19.3%), and then for preparation by hand sanding, with a PAR% of 6.8% (95% CI = 0.0%, 13.1%).

Safety Practices

Safety practices were also evaluated including dust containment and cleanup methods. The dust containment practices evaluated included wetting methods, sealing windows, sealing ventilation ducts, keeping entry door closed, placing a plastic flap over the entry, using a drop cloth for the floor, using a high-efficiency particulate air (HEPA) filter, covering furniture, and having a work enclosure. The cleanup practices evaluated included frequency of cleaning while work was performed, use of vacuum, use of HEPA-filtered vacuum, and use of wet cleaning agents and mops. One or more of these safety practices were reported by 31% of the 70 participants who had any type of interior renovation work. There was a suggestive, but nonsignificant, benefit in the use of wet methods to contain (OR = 0.3, 95% CI = 0.1, 1.2) and clean up (OR = 0.7, 95% CI = 0.2, 2.1) dust relative to work done without these safety practices. Otherwise, there was no evidence of a protective effect, although small numbers precluded formal statistical analysis of these factors.

Who Performed the Renovation or Repair Work

Building maintenance staff or hired contractors performed 80% of the interior renovation or repair jobs. However, the risk for elevated BLLs was not associated with the type of individual performing the renovation or repair work once we accounted for the effect of paint preparation by sanding.

DISCUSSION AND CONCLUSIONS

We found that renovation and repair work that includes preparing an interior surface for painting, especially if by hand sanding, and work that spreads dust and debris throughout the home increased the risk of elevated BLLs for children in our study population. We also found that some type of renovation and repair work occurs commonly in homes occupied by young children in the target areas of New York City, although there is little or no overall association between renovation and risk for elevated BLLs. Our study indicates that renovation activities associated with elevated BLLs most likely account for a fairly small, although nontrivial, proportion (approximately 10%) of children with elevated BLLs in the target neighborhoods of New York City. However, the confidence intervals around the estimated population-attributable risk percentage are wide. If we apply this estimate to the total number of children with elevated BLLs who resided within the areas with the ZIP codes targeted by our study during 1998, approximately 125 of these children developed harmful levels of lead in their blood from exposures associated with renovation and remodeling in 1998 (J. Leighton, personal communication and unpublished data, 1999).

Our results have some similarities and some differences to those of the only other controlled study of renovation-remodeling and elevated BLLs in children. In 1999, EPA published a retrospective case-control study using childhood blood lead level data from 1996 in Wisconsin and a parental interview in 1997 about home renovation factors.[14] EPA also found that renovation and repair in older homes was common, with 67.2% of respondents having some type of work done within 12 months preceding their child's blood lead test; this compares with 35% of respondents in our study during the 6-month exposure period before the child's blood lead test. Although association between any event and elevated BLL was similar in magnitude to the one we estimated (OR = 1.3), it was marginally significant (95% CI = 1.0, 1.7) in their larger (n = 3,654) study than in our findings (OR = 1.2, 95% CI = 0.7, 2.1). The EPA study also detected increased risks with preparing an inside surface for painting (OR = 1.3, 95% CI = 1.0, 1.8), specifically by hand sanding or scraping (OR = 1.2, 95% CI = 1.0, 1.6), compared with ours (OR = 3.5, 95% CI = 1.1, 10.9). The lower relative risks in their study were perhaps due to the longer time period allotted between exposure and measurement of BLLs. Other paint removal methods associated with case status in the EPA study, but reported too infrequently for analysis in our study, include strong associations by either open-flame torch or by heat gun and weaker associations by wet abrasive methods and by chemical paint removal. Although some differences between the EPA study and ours would be expected on the basis of differences in the study locations (most of Wisconsin versus selected neighborhoods in New York City), the consistency of results lends credibility to the conclusion that home renovation or repair work involving interior paint preparation contributes to a nontrivial proportion of elevated BLLs in children.

Our study has some important limitations. The sample size, while adequate for assessing overall risk associated with renovation, afforded limited power to detect small effects for individual types of work or interactions between factors. As in any retrospective study, nondifferential exposure misclassification may have occurred if respondents forgot about renovation or repair work events, relevant dates, or specific work tasks. Differential misclassification of exposure could have occurred if case families were more likely to recall renovation and repair work, but it was minimized by the following three strategies: (1) interviewers were blinded to case status; (2) the interviews were promptly timed (within 45 days of the child's blood test); and (3) the questionnaire minimized subjective responses by asking specific, operational questions about the type of renovation or repair work.

Because other risk factors for lead poisoning predominate in low-income neighborhoods (e.g., deteriorated housing conditions and poor nutrition), our study might overestimate the PAR% associated with home renovation and repair for impoverished children. Yet, although we sampled only children from medium-to-higher-income neighborhoods, we recruited children who had their blood tested at the NYCDOH Public Health Laboratory. This laboratory primarily serves clinicians providing health care for children from lower-income families (e.g., New

York City child health clinics) and even within New York City ZIP codes, income levels can vary from block to block. As a result, we may have underestimated the PAR% for these New York City neighborhoods.

Our study indicates that both homeowners and contractors may perform risky home renovation and repair work and may be unaware of potential lead hazards or of work practices that may minimize the risk for lead exposure. To raise awareness of the potential hazards, targeted education could be implemented through home supply and retail stores, adult education courses, the licensing process for contractors, and the process for obtaining building permits. Education and other prevention strategies should target jobs that involve interior paint preparation in older homes. Educational efforts should also focus on the importance of proper cleanup methods during and on completion of work and on the availability of dust clearance tests.

This study supports the new laws effective in New York City as of November 1999. These regulations prohibit the use of dry scraping or dry sanding of lead-based paint or paint of an unknown lead content in any dwelling unit. The regulations also mandate safe work practices, including appropriate cleanup methods, when repairing lead-based paint hazards or paint that is presumed to contain lead-based paint in all pre-1960 multiple-dwelling units with children under 6 years of age. In certain circumstances, dust testing is required when lead-based paint housing violations are being addressed. Education efforts, however, must be emphasized to inform landlords, contractors, painters, and tenants about the hazards of lead poisoning and the steps needed for its prevention.

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