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The association between demolition activity and children's blood lead levels

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Abstract

Urban renewal efforts are a priority for many American cities. As efforts to reconstitute urban centers increase, the demolition of old, deteriorated structures has accelerated. Recent studies have identified demolitions as a potential source of environmental lead exposure. We conducted a study examining the relationship between demolition activity and blood lead levels of children residing in neighborhoods where demolition activity occurred.

A retrospective cohort study was conducted in St. Louis City, Missouri. The study period was January 1, 2002 to December 31, 2002. Data were obtained from the Missouri Childhood Lead Poisoning Prevention Program's (CLPPP) lead surveillance system and St. Louis Demolition Permit Database. Children were considered exposed to a demolition if they had a blood lead test within 45 days of any demolition on a census block. Exposure was classified as both a dichotomous (yes/no) and a categorical (none/one/multiple) variable and was analyzed separately. Linear regression models were developed to determine effects of demolitions on blood lead levels.

A total of 1196 children 6–72 months of age living in 395 census blocks were included. 314 (26.3%) were exposed and 882 (73.7%) were unexposed to a demolition. In an adjusted model, exposure to multiple demolitions was found to have significant effects on children blood lead levels (coefficient = 0.281; 95% CI = 0.069, 0.493; *P*-value = 0.010). Age of the child, race, and age of housing where children's resided were also significant predictors.

This study suggests that multiple demolitions within a census block may significantly increase children's blood lead levels. The findings may be useful to municipal planners in older cities where demolitions are being used as an urban renewal tool.

Keywords: Lead; Lead poisoning; Child health; Environmental health; Urban renewal

1. Introduction

Lead is a major environmental health hazard for children in the United States and lead poisoning represents a health disparity, with low-income and minority children disproportionately affected (CDC, 2002, 2005). Although deteriorated paint in the household has been identified as the primary source of lead exposure, researchers have recently identified urban housing demolitions as an additional potential source of lead exposure in the environment (Farfel et al., 2003, 2005). Farfel et al. (2003) found increased lead dustfall rates within a 10 m radius of residential demolition sites during and immediately after demolition and debris removal. Further study of settled lead dust within 100 m of demolitions found increases at levels considered a public health concern (Farfel et al., 2005). It is postulated that settlement of lead dust following housing demolition can become an ambient pathway for lead exposure and a potential source of

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Abbreviations: CLPPP; Childhood lead poisoning prevention program; CDC; Centers for disease control and prevention; HUD; department of housing and urban development; EPA; Environmental protection agency; EBL; elevated blood lead level; CI; Confidence interval; NAHB; national association of home builders

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interior and exterior lead exposure through tracking, re-aerosolization, and re-deposition (Farfel et al., 2005). A study conducted by Diorio (1999) found dust lead loadings increased in houses neighboring demolition sites. The result was more pronounced for demolitions done without proper containment practices (Diorio, 1999).

Demolition activities are undertaken as part of neighborhood development and revitalization efforts. Aging and derelict housing is usually targeted for demolition. Approximately 1.8 million older housing units are estimated to be demolished nationwide this decade (President's Task Force, 2000). The US Department of Housing and Urban Development (HUD) estimates that 1.2 million households with lead-based paint hazards house low-income families with children under 6 years of age (Jacobs et al., 2002), the demographic group at highest risk for elevated blood lead levels (EBLs) . The demolition of these housing structures may result in the generation of an exposure hazard through the dispersion of lead in the environment.

Urban renewal efforts are a priority for many American inner cities. As efforts to reconstitute urban centers increase, the demolition of deteriorated structures has accelerated. Nationwide, an estimated 245,000 residential units and 45,000 non-residential structures are demolished every year (National Association of Home Builders (NAHB), 1998). During the past several years, St. Louis City, Missouri has undergone significant reconstruction, a major component of which has been the demolition of old residential and commercial structures. From 2001 to 2002, St. Louis City issued permits for the demolition of more than 2000 buildings. St. Louis is similar to other old, urban areas in that there are a significant number of children with elevated blood lead levels residing in homes built prior to 1978. Demolition of these structures may prove to be a source of unintended lead exposure since buildings constructed prior to 1960 are known to contain heavily leaded paint (Washington State, 2005).

Although demolitions of urban residential housing has been identified as a potential source of environmental lead exposure, its effects on children's blood lead levels has not yet been quantified. A preliminary investigation of the correlation between demolitions and EBLs in St. Louis City, using spatial analysis techniques, found a significant spatial correlation (Patridge et al., 2004). The purpose of this study is to examine the relationship between demolition activity and blood lead levels of children aged 6–72 months residing in neighborhoods where demolition activity occurred.

This study uses an environmental public health tracking approach; this approach examines the feasibility and validity of linkage between different data sources for health outcome research. This study utilized data from the St. Louis Demolition Permits database, the Tax Assessor database, the US Census, and from the Missouri Childhood Lead Poisoning Prevention Program's (CLPPP) blood lead surveillance database.

2. Materials and methods

2.1. Study setting and population

A retrospective cohort study was conducted in St. Louis City, Missouri. The sampling frame included data from two routinely collected data sources. Blood lead data and related covariate information were abstracted from the CLPPP blood lead surveillance database. The system collects data on all blood lead tests conducted on children in Missouri. Only blood specimens analyzed by laboratories certified for lead analysis are included in the system. Demolition data were obtained from the St. Louis Demolition Permit Database. The demolition database contains over 15,000 records on demolished structure type, size, and address. The study utilized 2002 data for the analysis because this time corresponded to a large number of demolitions and a high lead screening rate; 40.5% of 28,639 children between the ages of 6–72 months were screened in 2002. Demolition data collected between January 1, 2002 and December 31, 2002 were eligible for inclusion in the study.

Children were eligible for inclusion if they were between 6 and 72 months of age and resided on a census block where at least one demolition occurred in 2002. Only one record per child was included in the analysis to avoid over-representation of children with chronic blood lead elevations. In cases where a child had multiple lead tests in 2002, the maximum lead result was chosen.

Demolition activity is not a random process. That is, demolitions are concentrated in areas of inner cities where substandard housing is predominant. Since substandard housing and related sociodemographic characteristics are strong predictors of elevated lead levels, we restricted our sample to children residing on census blocks where demolition activity occurred to control for unknown and unmeasured confounding variables including socioeconomic status.

2.2. Exposure classification

Children were categorized as 'exposed to a demolition' if their blood lead test was within 45 days after a demolition was completed on the census block where the child lived. A child could be exposed to multiple demolitions within the 45-day time frame. A period of 45 days was chosen as a lead clearance period for any one demolition. The half-life of lead in blood is 28–36 days (Griffin et al., 1975; Rabinowitz et al., 1976). Therefore, we have chosen a conservative estimation as very high lead exposure or continuous exposure could sustain the blood lead level after 45 days. Also, this will allow environmental transport of lead particles through tracking or re-deposition. Children were categorized as 'unexposed to a demolition' if they lived on a census block where at least one demolition occurred in 2002 and their lead test preceded the demolition. This was done to ensure that the blood lead results in these children reflected background levels of lead and was not influenced by exposure to demolition activity.

Direct measurement of the dispersion of lead particles from study demolitions was unavailable. In lieu of these data, residence on a (census) block where at least one demolition occurred was used as a surrogate to demarcate exposure area to demolition hazards. Census blocks were chosen because they represent the smallest unit of aggregation for which pertinent covariate information could be obtained. Also, previous research found noteworthy increases in settled dust within 100 m of the demolition (Farfel et al., 2005). We chose demolitions based on their completion date. The average length from issuance of the permit to completion of the demolition was 73 days. All demolitions, regardless of structure type, were included in the analysis.

2.3. Study sample

Between January 1, 2002 and December 31, 2002, 12,246 St. Louis City children had a blood lead test. Children between the ages of 6 and 72 months were eligible for this study. This represents the population at highest risk for an EBL. Fifty-nine records were excluded due to the child's age, 53 records were excluded due to null or zero values for blood lead results, and 76 records were excluded because they were found to be duplicates. Zero or null values for blood lead results indicate that the test was not performed or that valid results were not obtained. If blood lead levels were below the detection limit, a value that is half of the detection level was assigned. A total of 1711 children had multiple lead tests [range 2–11] in 2002. One record per child was retained in the dataset excluding all others. The remaining 9786 records were geocoded to 2000 US census blocks. Thirty records were excluded because they did not geocode to St. Louis City. This resulted in a dataset with 9756 potentially eligible children.

The dataset of potentially eligible children was merged with the St. Louis City Demolition Permit Database on census block. There were 2188 children in 507 census blocks where at least one demolition occurred. Of these, 992 children were excluded because they had their lead test 45 days or more after the demolition. The final data set contained records for 1196 children and a total of 710 demolitions on 395 census blocks.

2.4. Statistical analysis

Descriptive statistics were performed to determine the demographic distribution of the study population. Chi-square statistics were generated for categorical variables and means were compared for continuous variables to determine whether there were significant differences between exposed and unexposed children. The main exposure variable (exposure to demolition activity) was categorized both according to exposure status (yes/no) and number of exposures (none, one, and multiple).

Univariate and multivariate linear regression analysis was run separately for both exposure variables. Covariates considered were child's age, sex, the year the house in which the child resided was built (year house built), and race. For 21 records, sex was missing data. For these records, sex was imputed using random assignment based on the distribution of sex in the overall dataset. Age was categorized into three groups: 6–11 months, 12–35 months and 36–72 months. Housing age for the residences of 1140 children was collected from the St. Louis City Tax Assessor Dataset. Age of adjacent housing units was used to estimate housing age for 56 records for which this information was missing. Race categories considered were African-American, White and Other. Due to small numbers, Whites and Others were collapsed into one race category for all regression analysis. For 51 records, race was missing. The missing data was handled two ways in the analysis. First, the model was run with the missing data excluded. Next, the missing data were modeled. The results were consistent between both approaches. Therefore, we report only results from the analysis excluding records with missing race data. The significance level was set at 0.05; 95% confidence intervals (CI) and *P*-values were reported for all coefficients for both univariate and multivariate models.

The dependent variable, children's blood lead level, was found to be non-normally distributed. This variable was log-transformed and used in all analyses. All analyses were performed using Stata® (Stata version 9.0 for Windows; StataCorp LP, College Station, TX, USA) and SAS® (SAS version 9.1 for Windows; SAS institute Inc., Cary, NC, USA) software packages.

3. Results

3.1. Description of the study population

The study included 1196 children in 395 census blocks (Table 1); of these, 314 (26.3%) were classified as exposed to at least one demolition, 882 (73.7%) were classified as unexposed. The study population was split evenly between males and females and was predominantly African-American (84.4%). The mean age of children was 35.5 months. The majority of blood lead tests were venous samples (86.5%) and the geometric mean blood lead level was 5.55 μg/dL; 20.4% of sample children had lead levels ⩾10 μg/dL. The median year of housing construction was 1909 with 92.4% of children living in houses built prior to 1950. All but 13 children (1.09%) resided in housing built before 1978. The majority of children exposed to demolition activity lived on a census block where only one demolition occurred. Comparing exposed and unexposed children (Table 2) on demographic characteristics, including sex, race, age, blood sample type, and year house built, no significant differences were detected between groups.

Table 1
Demographic, housing and other characteristics of the study population ($N = 1196$)

Variable	*n* (%)
Sex	
Male	604 (50.5)
Female	571 (47.7)
Missing	*21* (*1.8*)
Race	
African-American	1010 (84.4)
White	108 (9.0)
Other	27 (2.3)
Missing	*51* (*4.3*)
Age in months [Mean (SD)]	[35.47 (18.209)]
Age category	
6–11 months	50 (4.2)
12–35 months	559 (46.7)
36–72 months	587 (49.1)
Blood sample type	
Venous	1034 (86.5)
Capillary	140 (11.7)
Missing	*22* (*1.8*)
Blood lead [Geomean (95% CI)] μg/dL	[5.55 (5.34, 5.76)]
Exposure to demolition	
Yes	314 (26.3)
No	882 (73.7)
Number of demolitions	
None	882 (73.7)
One	274 (22.9)
Multiple	40 (3.3)
Year house built	
Before 1950	1105 (92.4)
1950 and after	91 (7.6)
Year house built [Median (min, max)]	[1909 (1879, 1989)]

3.2. Regression analyses

In an unadjusted model with exposure to demolition defined as yes or no, being exposed to a demolition was found to be associated with an increase in blood lead level (coefficient = 0.096; 95% CI = 0.009, 0.183; *P*-value = 0.031). An unadjusted analysis was conducted using demolitions categorized as none, one, or more than

Table 2
Bivariate association between demolition status and other characteristics ($N = 1196$)

Variable	Unexposed ($n = 882$) n (%)	Exposed ($n = 314$) n (%)	P-value
Sex			0.642
Male	432 (49.0)	149 (47.5)	
Female	450 (51.0)	165 (52.5)	
Race			0.064
African-American	731(82.9)	279 (88.9)	
White	86 (9.8)	22 (7.0)	
Other	24 (2.7)	03 (1.0)	
Missing	*41 (4.6)*	*10 (3.2)*	
Blood sample type			0.104
Venous	753 (87.2)	281 (90.6)	
Capillary	111 (12.8)	29 (9.4)	
Age category			0.769
6–11 months	35 (4.0)	15 (4.8)	
12–35 months	416 (47.2)	143 (45.5)	
36–72 months	431 (48.9)	156 (49.7)	
Year house built			0.825
Before 1950	814 (92.3)	291 (92.7)	
1950 and after	68 (7.7)	23 (7.3)	
House build year [Median (SD)]	[1909 (19.9)]	[1909 (19.4)]	0.671
Age in months [Mean (SD)]	[35.4(18.2)]	[35.7(18.3)]	0.775

one to determine if exposure to multiple demolitions is related to higher blood lead levels. In this model, exposure to one demolition was not associated with an increased blood lead level (coefficient = 0.07; 95% CI = −0.02, 0.16; P-value = 0.155). However, exposure to more than one demolition was associated with a higher blood lead level (coefficient = 0.296; 95% CI = 0.08, 0.51; P-value = 0.007) (Table 3).

Covariates considered in the multivariate model included year house built, sex, child's age, and race. In a multivariate model considering the effect of demolitions (yes or no) on blood lead level, exposure to a demolition was not significantly associated with increased lead levels (coefficient = 0.075; 95% CI = −0.013, 0.163; P-value = 0.093) (Table 4). Year house built (coefficient = −0.004; 95% CI = −0.006, −0.002; P-value = <0.001), child's race (coefficient = 0.290; 95% CI = 0.170, 0.411; P-value = <0.001), and child's age were significant predictors of higher blood lead levels. In an adjusted model exploring the relationship between multiple demolitions and blood lead levels, exposure to multiple demolitions, controlling for relevant covariates, was predictive of higher blood lead levels (coefficient = 0.281; 95% CI = 0.069, 0.493; P-value = 0.010). In this model, year house built (coefficient = −0.004; 95% CI = −0.006, −0.002; P-value = <0.001), race (coefficient = 0.289; 95% CI = 0.169, 0.410; P-value = <0.001), and child's age were also significant predictors. The results of the multivariate model are illustrated in Tables 4 and 5.

Table 3
Unadjusted regression analysis of log-transformed blood lead levels and covariates ($N = 1196$)

Variables	Coefficient (95% CI)	Standard error	p-value
Sex			0.311
Female	—	—	
Male	0.040 (−0.037, 0.116)	0.0392	
Race[a]			<0.001[b]
White and other	—	—	
African-American	0.297 (0.176, 0.418)	0.0610	
Age			
6–11 months	—	—	
12–35 months	0.318 (0.122, 0.513)	0.0997	0.002[b]
36–72 months	0.260 (0.064, 0.455)	0.0995	0.009[b]
Year house built	−0.004 (−0.006, −0.002)	0.0010	<0.001[b]
Demolitions			0.031[b]
No	—	—	
Yes	0.096 (0.009, 0.183)	0.0445	
Demolitions			
None	—	—	
One	0.067 (−0.025, 0.158)	0.0467	0.155
Multiple	0.296 (0.082, 0.511)	0.1093	0.007[b]

[a] Missing ($n = 51$) values not taken in to account.
[b] Statistically significant at 0.05 level.

Table 4
Adjusted association between log-transformed blood lead levels and demolitions ($N = 1145$)[a]

Variable	Coefficient (95% CI)	Standard error	P-value
Sex			0.395
Female	—	—	
Male	0.034 (−0.044, 0.111)	0.0395	
Race			<0.001[b]
White and other	—	—	
African-American	0.290 (0.170, 0.411)	0.0614	
Age			
6–11 months	—	—	
12–35 months	0.347 (0.149, 0.545)	0.1010	<0.001[b]
36–72 months	0.269 (0.072, 0.467)	0.1007	0.008[b]
Build year	−0.004 (−0.006, −0.002)	0.0010	<0.001[b]
Demolitions			0.093
No	—	—	
Yes	0.075 (−0.013, 0.163)	0.0448	

[a] Missing ($n = 51$) values not taken in to account.
[b] Statistically significant at 0.05 level.

To further explore the effect of race on children's blood lead levels, a race and demolition interaction was considered. Race stratified models were also run. No significant interaction was found between race and demolition in either model (data not shown). The race stratified models yielded the same results as the non-stratified models (data not shown). The geographic distribution of the study sample by race was mapped using ESRI® ArcMap™ software (ESRI® ArcMAP™ Desktop software package, version 9.0; Inc., USA) (Fig. 1).

Table 5
Adjusted association between log-transformed blood lead levels and number of demolitions ($N = 1145$)[a]

Variable	Coefficient (95% CI)	Standard error	P-value
Sex			0.372
Female	—	—	
Male	0.035 (−0.042, 0.113)	0.0395	
Race			<0.001[b]
White and other	—	—	
African-American	0.289 (0.169, 0.410)	0.0613	
Age			
6–11 months	—	—	
12–35 months	0.347 (0.149, 0.544)	0.1008	<0.001[b]
36–72 months	0.270 (0.073, 0.468)	0.1005	0.007[b]
Build year	−0.004 (−.006, −0.002)	0.001	<0.001[b]
Demolitions			
None	—	—	
One	0.044 (−0.049, 0.137)	0.0472	0.35
Multiple	0.281 (0.069, 0.493)	0.1081	0.010[b]

[a] Missing ($n = 51$) values not taken in to account.
[b] Statistically significant at 0.05 level.

From this figure it is apparent that African-American and other races are geographically separated. In the absence of census block level data in the 2000 US Census, median household income of blockgroups exclusively belonging to African-American population were compared to those exclusively belonging to white and other races. African-Americans were found to have significantly lower median household income than white and other races (data not shown) (US Census Bureau; Census 2000).

4. Discussion

4.1. Findings

Demolition of old housing is an integral part of revitalization efforts in many urban cities but has been shown to increase ambient dust in surrounding areas to levels exceeding US EPA standards for residential floor lead loadings (Farfel et al., 2003). This suggests that demolition activity in low-income urban areas may exacerbate lead hazards for neighborhood residents and pose a new risk for vulnerable populations. In this study, we evaluated the effect of structure demolition on children's blood lead levels. After controlling for known risk factors, being exposed to a single demolition was not related to an increase in blood lead level. However, being exposed to multiple demolitions on a residential block was associated with a significant increase in children's blood lead levels. This is the first study to link the impact of demolitions on children's blood lead levels. Recent literature suggests that a high-risk population may be vulnerable to additional risk from cumulative lead exposure from multiple demolitions (Farfel et al., 2005). Our findings support these results. While a single demolition may not be a sufficient hazard for children, multiple demolitions may combine with other sources of exposure to increase blood lead levels. However, further research is needed to determine the exact route and pathway relevant for this ambient lead exposure source.

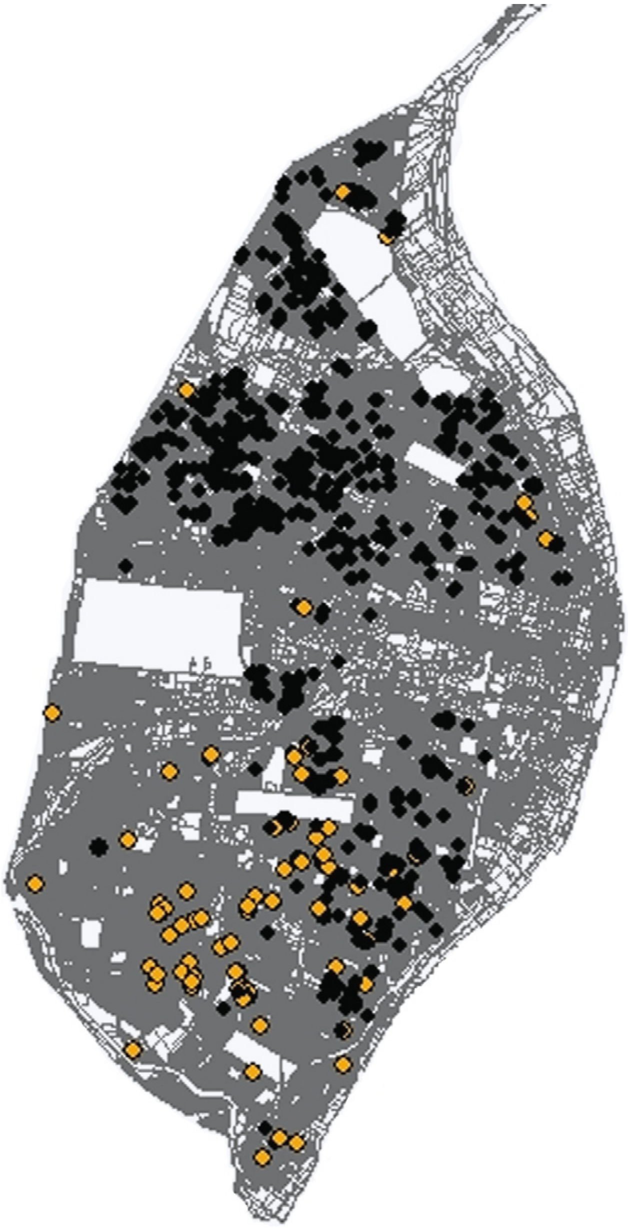

Fig. 1. Geographic distribution of residence of children by race click here to download high resolution image. ■, African-American; □, White and other.

The finding that the age of the house and the child's age are significant predictors of increasing blood lead levels is consistent with our knowledge of lead exposure. However, the finding that race was a significant predictor despite selection procedures designed to minimize racial differences was unexpected and suggests the occurrence of residual confounding. The variability by race is generally assumed to be related to differences in housing characteristics and socioeconomic status. In our sample, there was no difference between racial groups regarding the year the house was built and the age of structures demolished. From Fig. 1, it is apparent that African-Americans and other races are geographically separated. Further, African-Americans were found to have significantly lower median household income than white and other races. Therefore, differences in actual housing condition and neighborhood characteristics may explain the significance of race in our models. The variable 'age of housing' does not appear to have adequately accounted for these differences. This leads to the hypothesis that indiscriminate use of age of housing and inner city residence, as a surrogate to characterize risk may not be robust across racial groups. This finding has important public health practice implications. Current efforts to reach the *Healthy People 2010* goal of eliminating lead poisoning rely on a housing-based approach as the primary prevention of EBLs (EPA, 2000). Surrogates (namely housing age and socioeconomic status) are used to identify homes for intervention. To be effective, these surrogates must be valid measures of lead hazards for all at-risk children. Our findings suggest that these surrogate measures may not be appropriate for all sub-populations.

4.2. Limitations

This study had several limitations that should be considered in interpreting the results. First, direct measurements of home lead hazards and condition of housing for the child's residence were unavailable. To approximate these variables, multivariate models included the age of the house of residence. Second, data on neighborhood characteristics, beyond that available from the US Census, were not available. This is significant in terms of the finding that exposure to multiple demolitions was associated with an increase in lead levels, while exposure to a single demolition was not. To the extent that the occurrence of multiple demolitions represents the deteriorating condition of other homes on the same block, effects of multiple demolitions would be confounded by the condition of the child's residence.

Misclassification of exposure could have occurred; census blocks as an indicator of exposure proximity may misclassify some children on both exposure status and exposure to number of demolitions. This 'edge effect' can happen when a child living on the block border is exposed to a demolition from an adjacent block. Also, demolitions occurring prior to 2002 were not included in the analysis. Children who were exposed to demolitions from November 16, 2001 to December 31, 2001 could have had an increase in their blood level due to exposure to these demolitions. Even if the misclassification on both situations is assumed to be differential, the direction of the bias will be towards the null. The inclusion of all demolitions, regardless of structure type and age, may also have introduced a bias towards the null since not all structures contained lead-based paint.

Dispersion data for lead particles after demolition were not available. As a result, exposure was assigned using residential geographic location at block levels. Direct measurement of hazard dispersion and information on containment practices would increase the precision of exposure assignment and limit misclassification. Finally, the maximum lead value was used to represent children with multiple lead tests. This increased the probability of detecting an association.

This study demonstrates the successful implementation of the environmental public health tracking approach to environmental research. As such we utilized secondary data. Longitudinal studies with direct measures of environmental lead are needed to shed further light on the relationship between demolitions and children's blood lead levels.

5. Conclusion

As urban renewal efforts take place across the country, consideration should be given to the potential impact that demolition of older structures has on children's risk for exposure to lead. In areas where multiple demolitions are planned, an emphasis on containment practices and efforts to inform the neighborhood of increased risk may be warranted.

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