The Effectiveness of Housing Policies in Reducing Children’s Lead Exposure

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ABSTRACT

Objectives. This study evaluated the relation of housing policies to risk of subsequent lead exposure in addresses where lead-poisoned children had lived.

Methods. Addresses where children with lead poisoning lived between May 1992 and April 1993 were selected from lead screening registries in 2 northeastern states differing in their enforcement of lead poisoning prevention statutes. Blood lead levels of subsequently resident children, exterior condition, tax value, age, and census tract characteristics were collected. The odds of elevated blood lead levels in subsequently resident children were calculated with logistic regression.

Results. The risk of identifying 1 or more children with blood lead levels of 10 μg/dL or greater was 4 times higher in addresses with limited enforcement. Controlling for major confounders had little effect on the estimate.

the age of housing, and tenancy, were extracted from the 1990 census STF 3A file.\textsuperscript{15,16}

\section*{Statistical Analyses}

Census tract characteristics were compared for addresses where children were tested during the study period. Because the number of addresses in the census tracts varied from 1 to 21, a weight was constructed from the inverse of the variance of the number of addresses to reduce the influence on the group mean of census tracts with only 1 observation.

For the 4 addresses that were vacant lots in 1998, the mean housing condition value, 1 element in disrepair, was imputed. It was assumed that the interior windows were not replaced before demolition. For vacant lots and 8 other addresses, tax values were unknown and the median value of owner-occupied housing for the census tract was used. Models with imputed values did not differ significantly from models in which missing values were permitted to “float.”

A bivariate logistic regression model was fitted to determine the odds that an address would house at least 1 subsequent child with blood lead levels of 10 µg/dL or greater in comparisons of strict and limited enforcement addresses. The model was adjusted for differences between enforcement groups. Three variable models that showed a 10% or greater change in the exposure covariate were classified as potential confounders of the relation. Including an interaction term, exterior condition and wooden exterior, did not improve the fit of the final model (log likelihood ratio test, \(P > .10\)).

\section*{Results}

In all, 679 test results from children 6 years or younger were recorded during the study period. In both groups, the median number of children tested was 3 per address.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|}
\hline
Census Variable                  & Strict Enforcement & Limited Enforcement \\
\hline
\text{No. of persons, mean (SD)} & 4279 (±1672)        & 4530 (±1978)        \\
\text{Percentage of persons in urban areas, mean (SD)**} & 94% (±14%)          & 99.7% (±2%)         \\
\hline
\text{Tracts with proportion of Black residents, no. (%)} & & \\
<0.01 & 8 (30%) & 8 (24%) \\
0.01–0.03 & 8 (30%) & 7 (21%) \\
0.03–0.08 & 8 (30%) & 7 (21%) \\
>0.08 & 3 (11%) & 12 (35%) \\
\hline
\text{No. of children younger than 6 y, mean (SD)} & 439 (±225) & 478 (±218) \\
\text{Percentage of persons older than 6 y living in same house in 1985, mean (SD)} & 53% (±10%) & 50% (±11%) \\
\hline
\text{Median income (SD)**} & $26,933 (±8,340)$ & $21,654 (±7,399)$ \\
\text{Proportion of households receiving public assistance, no. (%)*} & & \\
<0.08 & 6 (22%) & 7 (21%) \\
0.08–0.15 & 11 (41%) & 5 (15%) \\
>0.15–0.22 & 5 (19%) & 11 (32%) \\
>0.22 & 5 (19%) & 11 (32%) \\
\hline
\text{Proportion of units in buildings with >4 housing units, no. (%)} & & \\
<0.14 & 7 (26%) & 10 (29%) \\
0.14–0.25 & 5 (19%) & 8 (24%) \\
>0.25–0.39 & 7 (26%) & 8 (24%) \\
>0.39 & 8 (30%) & 8 (24%) \\
\hline
\text{Median year built (SD)} & 1943 (±8) & 1946 (±11) \\
\text{No. of units built before 1950, mean (SD)} & 1147 (±499) & 1113 (±477) \\
\text{Percentage of owner-occupied units (SD)} & 40% (±21%) & 34% (±17%) \\
\hline
\end{tabular}
\caption{Comparison of Average Census Characteristics\textsuperscript{*} in Tracts With Addresses With Lead-Poisoned Children in 1992 and Children Tested From 1993 to 1998}
\end{table}

\*The number of addresses in census tracts ranged from 1 to 21. Weights based on the inverse of the variance would reduce the influence of census tracts with few addresses. When weights were used to compare the enforcement areas, none of the characteristics were statistically different.

\*t test for means or \(\chi^2\) for categoric variables, comparison \(P = .05\) vs \(P = .15\).

\*\*t test for means or \(\chi^2\) for categoric variables, comparison \(P = .05\) vs \(P = .15\).

The mean venous blood lead levels for the children were 7.6 µg/dL (±4.8; \(n = 111\)) and 8.9 µg/dL (±7.2; \(n = 547\)) for the strict and limited enforcement addresses, respectively (\(P = .02\)).

\section*{Census Tract Characteristics}

For several important census tract characteristics, the mean value of the limited enforcement addresses was significantly different from that of the strict enforcement addresses (Table 1). However, when the values were adjusted with weights to account for the number of addresses in a given census tract (range = 1–21 addresses per census tract), none of the differences in characteristics approached statistical significance.

\subsection*{Address Characteristics}

In both groups, most addresses were 3-unit buildings (84% in strict and 87% in limited) built during the 1920s and early 1930s (Table 2). Six addresses (4 strict and 2 limited enforcement, \(P = .01\)) were built after 1950. Most addresses were in good condition, with an average of 1.3 structural elements in disrepair in strict enforcement addresses and 0.9 structural elements in disrepair in limited enforcement addresses. The tax valuation differed significantly—strict enforcement addresses were valued approximately $40000 more on average than were limited enforcement addresses. Limited enforcement addresses were more likely to have wooden exteriors (45 vs 8, \(P = .05\)) and less likely to have replacement windows (\(P = .001\)).

\subsection*{New Cases}

Limited enforcement addresses were 4.6 (95% confidence interval [CI] = 2.0, 11.0) times more likely to house at least 1 subsequent child with blood lead levels of 10 µg/dL or greater (Table 3). In models that controlled for the major covariates, the risk of identifying at least 1 child with blood lead levels of 10 µg/dL or greater was 4.4 times (95% CI = 1.3, 15.3) higher in limited compared with strict enforcement addresses (\(P = .02\)). Limited enforcement addresses also were 6.6 (95% CI = 0.85, 51.5) times more likely to house at least 1 child with blood lead levels of 25 µg/dL or greater (data not shown).

\section*{Discussion}

Despite differences in the assessed value, the exterior conditions of the buildings were very similar. The groups differed by the number of addresses with painted, wooden exteriors and the number of addresses where inte-
Public policy is the result of a complex interplay of laws, regulations, and custom. Although these findings suggest that residential lead hazards were more likely in the limited enforcement addresses, the difference in risk of subsequent cases of blood lead elevation was not explained solely by these factors. Nor was it adequately explained by underlying poverty and related sociodemographic differences between the census tracts where the addresses were located.

Public policy is the result of a complex interplay of laws, regulations, and custom. Although policies are implemented across communities, they are designed to influence the lives of individuals. Thus, residents are “exposed” to the public policies in force in their communities. For lead poisoning, these policies include abatement of lead hazards in individual units, property owner liability, notification and referral for services of affected parties, screening, and public education.

The contribution of each factor is not well understood. However, both states in this study had established lead poisoning prevention programs with nearly universal screening and widespread public education. The difference between the rates of subsequent cases of blood lead elevation in addresses with lead-poisoned children in the past was likely the result of differences in enforcement of state housing statutes. In addition, although a direct association cannot be inferred between the overall prevalence of blood lead levels of 10 µg/dL or greater and the risk of recurrence in housing with poisoned children, the prevalence of blood lead elevation in the limited enforcement county was approximately twice that in the strict county.\textsuperscript{15,17} This also may reflect the long-term effect of limited enforcement capacity.

This study had several limitations. First, blood lead testing was not controlled by the investigators. Differences in screening procedures may account for some of the differences in case identification, although the number of children tested in an address did not vary by enforcement status. Second, because the concentration of lead in paint was not measured at the addresses, addresses with limited enforcement may have been painted with more highly leaded paint. However, no evidence showed that paint sold in either area varied by lead concentration or that housing in either area was more or less likely to be painted with lead paint.

Our inability to measure some factors, such as race/ethnicity, known to increase risk for lead poisoning at the individual level, was clearly a limitation. However, our goal in this study was not to quantify the contribution of these factors to risk for lead poisoning but to control for confounding. Measurement theory implies that using aggregate values rather than individual values for these factors provides an attenuated estimate of enforcement status.\textsuperscript{18,19} Finally, it is unlikely that unidentified factors both varied significantly between the adjacent areas and were more influential than the covariates evaluated in this and other studies.

Conclusions

This study, to our knowledge the first to evaluate the effectiveness of housing policies

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### TABLE 2—Housing Characteristics in 1998 for 133 Units\textsuperscript{a} With Children Tested in 1993 to 1998, by Enforcement Status

<table>
<thead>
<tr>
<th></th>
<th>Strict Enforcement (n=33), No.(%)</th>
<th>Limited Enforcement (n=105), No.(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacant lot in 1998</td>
<td>2 (6%)</td>
<td>3 (3%)</td>
</tr>
<tr>
<td>Type of exterior*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood</td>
<td>8 (26%)</td>
<td>45 (44%)</td>
</tr>
<tr>
<td>Other</td>
<td>23 (74%)</td>
<td>57 (56%)</td>
</tr>
<tr>
<td>Interior windows**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;Half old</td>
<td>9 (29%)</td>
<td>63 (62%)</td>
</tr>
<tr>
<td>Replaced/new</td>
<td>22 (71%)</td>
<td>39 (38%)</td>
</tr>
<tr>
<td>Exterior structural element in disrepair or missing, mean (SD)</td>
<td>1.3 (±2)</td>
<td>0.9 (±1.6)</td>
</tr>
<tr>
<td>Mean tax valuation, $**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;63500</td>
<td>4 (13%)</td>
<td>29 (28%)</td>
</tr>
<tr>
<td>63500–85600</td>
<td>4 (13%)</td>
<td>29 (28%)</td>
</tr>
<tr>
<td>&gt;85600–116600</td>
<td>6 (19%)</td>
<td>27 (27%)</td>
</tr>
<tr>
<td>&gt;116600</td>
<td>17 (55%)</td>
<td>17 (17%)</td>
</tr>
<tr>
<td>Addresses with 3 dwelling units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>26 (84%)</td>
<td>89 (87%)</td>
</tr>
<tr>
<td>No</td>
<td>5 (16%)</td>
<td>13 (13%)</td>
</tr>
<tr>
<td>Built before 1950**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>27 (87%)</td>
<td>100 (98%)</td>
</tr>
<tr>
<td>No</td>
<td>4 (13%)</td>
<td>2 (2%)</td>
</tr>
<tr>
<td>Median no. of blood tests per address (n=137)</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Tests for children aged 18–36 mo (n=137)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>19 (59%)</td>
<td>33 (31%)</td>
</tr>
<tr>
<td>1–24</td>
<td>2 (6%)</td>
<td>13 (12%)</td>
</tr>
<tr>
<td>25–49</td>
<td>4 (13%)</td>
<td>30 (29%)</td>
</tr>
<tr>
<td>50–74</td>
<td>6 (19%)</td>
<td>20 (19%)</td>
</tr>
<tr>
<td>&gt;75</td>
<td>1 (3%)</td>
<td>9 (9%)</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Vacant lots (n=5) not included in calculations.
\textsuperscript{*}Test for means or \( t \) for categoric variables, .05 > \( P \) ≤ .15.
\textsuperscript{**}Test for means or \( \chi^2 \) for categoric variables, \( P \) ≤ .05.

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### TABLE 3—Adjusted and Unadjusted Odds Ratios (ORs) for Identifying At Least 1 Child With Blood Lead Levels of 10 µg/dL or Greater, by Enforcement Status

<table>
<thead>
<tr>
<th></th>
<th>Strict Enforcement</th>
<th>Limited Enforcement</th>
<th>Unadjusted\textsuperscript{d} OR (95% CI)</th>
<th>Adjusted\textsuperscript{d} OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addresses with ≥1 child identified</td>
<td>12 (38%)</td>
<td>77 (73%)</td>
<td>4.6 (2.0, 11.0)</td>
<td>4.4 (1.3, 15.3)</td>
</tr>
<tr>
<td>(no. of children = 22)</td>
<td>32\textsuperscript{e}</td>
<td>(no. of children = 167)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total no. of addresses</td>
<td>32\textsuperscript{e}</td>
<td>105</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\*Limited vs strict enforcement addresses.
\textsuperscript{d}Adjusted for proportion of households in the census tract receiving public assistance, percentage of toddlers living at the address, median census tract income, proportion of Black residents in census tract, and exterior condition of address.
\textsuperscript{e}One property where child was tested with a capillary blood sample was excluded.

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Note. CI = confidence interval.
in reducing lead exposure, suggested that strict enforcement of lead poisoning prevention statutes is an effective primary prevention strategy. It also confirmed health practitioners’ experience that lead-poisoned children are identified repeatedly in the same housing. Because relocation of lead-poisoned children is frequently the goal of lead poisoning prevention programs that lack the capacity to enforce abatement, our research also suggests the need to develop address-specific surveillance systems to track the blood lead levels of children living in the housing units. Such surveillance systems would allow programs to evaluate their effectiveness and would serve as lead-safe housing registries. Research regarding factors that influence owners’ maintenance practices, including owner occupancy, availability of funding, local enforcement capacity, liability, and the effect of lead hazard reduction on property values, also is needed.

Contributors
M.J. Brown planned the study, analyzed the data, and wrote the paper. J. Gardner contributed to the study design and implementation, the data analysis, and the writing of the paper. J.D. Sargent contributed to the study design, the interpretation of the data, and the writing of the paper. K. Swartz and H. Hu participated in the study design and the writing of the paper. R. Timperi contributed to the study design, the data analysis, and the writing of the paper.

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The study was approved by the Human Subjects Committees at the Harvard School of Public Health, the Rhode Island Department of Health, and Dartmouth Medical School.

References