Primary Prevention of Lead Poisoning: Protecting Children From Unsafe Housing

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Objectives. We examined the effects of changes in Rhode Island's Lead Hazard Mitigation Law in 2005 on children's blood lead levels.

Methods. We used 2005 to 2009 data from Rhode Island's Lead Elimination Surveillance System; city tax assessor records in Central Falls, Pawtucket, Providence, and Woonsocket, Rhode Island; and records of conformance to the state's lead hazard mitigation law, to assess the extent to which legislation changes resulted in minimizing children's exposure to lead.

Results. During the 5-year study, the proportion of properties that complied with the new law increased for properties that housed young children. However, the majority of rental properties did not comply with the law. Children's lead levels declined by approximately 1 microgram per deciliter on average in properties that did comply, demonstrating that the law could have a protective effect for children.

Conclusions. Legislation changes increased the proportion of properties that were certified as nonhazardous, leading to decreased blood lead levels for children living in these properties. However, legislation cannot be a highly effective primary prevention strategy if it does not cover all properties where children live and is not strictly enforced. (*Am J Public Health.* 2014;104: e119–e124. doi:10.2105/AJPH.2014.301908)

The prevention of childhood lead poisoning has been named one of the 10 great public health achievements in the United States for 2001 to 2010.[1] The impact of prevention programs has been dramatic. In the 1976 to 1980 National Health and Nutrition Examination Surveys of preschool children, 88.2% of preschool children had blood lead levels (BLLs) greater than or equal to 10 micrograms per deciliter. This percentage dropped to 0.9% in the 2003 to 2008 surveys.[1] Public health efforts have been highly successful, but the work remains incomplete. Recognizing that, even at very low blood levels, lead can have a lifelong negative impact, the Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) of the Centers for Disease Control and Prevention (CDC) has made a "Renewed Call for Primary Prevention," stating that, "Screening children for elevated BLLs and dealing with their housing only when their BLL is already elevated should no longer be acceptable practice."[2] Although children can be exposed to lead from many sources (including lead pipes, ceramic dishes, and even the air they breathe), the most prevalent source of exposure is from lead-based paint.[3]

One of the specific primary prevention approaches recommended by the ACCLPP was for local and state governments to "develop and enforce preventive lead-safe housing standards for rental and owner-occupied housing." To provide insight into the potential impact of this recommendation, we examined the experience of Rhode Island, a state that has long-established lead-safe housing requirements. In 2002, Rhode Island enacted sweeping changes to the state's lead hazard regulations as part of a comprehensive strategy to reduce lead poisoning incidence rates.[3] Starting in November 2005, Rhode Island's new law required landlords of non–owner-occupied rental properties to attend a 3-hour lead hazard awareness class, assess and fix lead hazards on the property, perform ongoing lead-safe home maintenance practices learned in the class, and obtain a lead hazard conformance certificate from a Certified Environmental Lead Inspector. Alternatively, rental property owners could meet higher standards for all of the rental units they owned by obtaining the Rhode Island Department of Health (RIDOH) lead safe certification (issued to properties after a more extensive inspection confirmed that all painted surfaces, water, or soil might contain lead, but all painted surfaces were intact or fully covered, or the lead present was at environmental levels permissible under RIDOH standards), or lead-free certification (issued to properties after a more extensive inspection confirmed that all painted surfaces, water, or soil contained no lead, or contained lead in amounts not sufficient to pose a health risk to children younger than 6 years).

We examined the effect of changes implemented as part of the Rhode Island Lead Hazard Mitigation Act on children's BLLs. Our broader study goal was to use Rhode Island's experience to help inform state and local governments that are considering establishing housing regulations in response to the CDC Advisory Council's recommendations, which seek to protect children from lead exposure. To reach these objectives, we first assessed the proportion of properties that complied with the new legislation in the first 5 years following the instituted changes. Next, we evaluated the overall effect of lead hazard conformance certification by comparing lead screening results before and after obtaining certification. Finally, to explore the potential impact of expanding the scope or level of enforcement of the regulations, we assessed the lead burden (i.e., average BLLs, rates of elevated BLLs, and rates of lead poisoning) in properties that were either not in compliance or were exempt from the legislation.

METHODS

To focus the study on areas where the lead burden would be the greatest, we examined housing built before 1978 (the year lead-based paint was banned in the United States[4]) in 4 of Rhode Island's core cities (Central Falls,

Pawtucket, Providence, and Woonsocket). These core cities have the highest percentages of children living in poverty,[5,6] and experience a disproportionate lead burden relative to other communities in the state. To further focus on the places where children at risk for lead poisoning live, we examined properties where a child had been living at the time they were screened for lead poisoning between 2005 and 2009.

Study Data and Measures

Multiple data sources were combined for this study. Blood lead screening data were collected by the RIDOH and provided the child's BLL, age, and address at the time of the test. The addresses were matched to city tax assessor records, which provided the property characteristics (type and age of property, occupancy unit count, and owner-occupancy status). In addition, data from the Rhode Island Housing Resources Commission (RIHRC) and the RIDOH on lead hazard mitigation certificates (LHMCs) were matched by address.

Blood lead surveillance data. The RIDOH requires that all children be screened with a blood test for lead poisoning at least twice by the time they are aged 36 months, with additional screening recommendations through age 6 years, depending on risk status. Almost three quarters of Rhode Island preschool children are screened at least once by 18 months of age.[7] All blood lead test results are maintained by the RIDOH in the Lead Elimination Surveillance System (LESS). We included all children with a confirmed blood lead test completed from January 1, 2005, to December 31, 2009, for children between ages 0 and 72 months (categorized into single years of age), inclusive (n = 71 731 test results for 39 712 children). All venous tests and all capillary tests with values less than 10 micrograms per deciliter were confirmed by the RIDOH. Capillary tests with values of 10 micrograms per deciliter or greater were classified as unconfirmed by RIDOH, unless they were repeated within 90 days to confirm the result. We therefore did not include unconfirmed test results (n = 24 children excluded for this reason). BLLs were examined 3 ways in this study: (1) as a continuous measure, (2) as a measure of elevated lead levels (BLL of ≥ 5 μg/dL vs < 5 μg/dL),[2] and (3) as a measure of lead poisoning (BLL of ≥ 10 μg/dL vs < 10 μg/dL).[2]

Children's addresses at the time of testing were standardized using ArcGIS Desktop version 10 (Esri, Redlands, CA), and then matched to a Master Lookup Table (MLT) to enable these data to be merged with other property-specific data sources. The MLT designates the parcel identification, plat, and lot for every known address. This tool, developed and maintained by The Providence Plan, is used as a crosswalk to add property-level information to addresses across all data sets used in this analysis. Because of the abundance of housing structures with 2 or more separate living units in our 4 study cities, addresses for each unit of a given property were matched to the shared property identification. We were able to match 94.3% (n = 23 870) of the addresses in the LESS database.

Housing characteristics. Using the unique parcel identifier on the MLT, we matched the addresses from LESS to the addresses in the city tax assessor records. The tax data were gathered from each city's tax assessor's office and provided information on the type (single-family, multifamily [2–5 units], apartment [6 or more units], or mixed-use [commercial and residential]) and age of the housing structure, occupancy unit count, and owner-occupancy status. Owner-occupancy status was determined by comparison of tax bill mailing addresses to physical addresses for Central Falls and Woonsocket. For Providence and Pawtucket, owner-occupancy was determined by a record of a homestead tax exemption (a type of property tax relief provided only to homeowners who use the property as their primary residence). Where available, we tried to obtain information closest to the study time frame. For Providence and Woonsocket, data were provided for 2005, 2007, and 2009. For Pawtucket, data were provided for 2005 and 2010. For Central Falls, data were provided for 2005 and 2011.

Conformance with lead hazard mitigation law. Legislation changes that took effect in 2005 required Rhode Island landlords to obtain a Certificate of Conformance, a document obtained from an authorized lead inspector or inspector technician that certified that the rental property was not hazardous for the tenants (i.e., all painted surfaces had intact paint, impact or abrasion surfaces were treated so lead-based paint was not subject to impact or abrasion, dust samples passed laboratory analysis, and soil within 5 feet of the property was covered and had no visible paint chips).[8] Records of these certificates and the dates they were obtained are maintained in a database by the RIHRC. To comply with the law, rental property owners might instead have their property certified as lead safe or lead-free. The lead safe and lead-free (LSLF) certificates are granted by and recorded at the RIDOH. Because all 3 types of certificates show compliance with the law, we included all and collectively refer to them as LHMCs for the remainder of this article.

Property owners who demonstrated owner occupancy for single-family units and 2 to 3 unit structures were deemed exempt from the requirements of the lead hazard mitigation law. Apartment buildings and structures with 4 or more living units were not exempt from the conformance requirement, regardless of owner occupancy. In addition, a unit built during or after 1978 was also considered exempt because lead-based paint was banned in 1978. We included indicators for exemption status because more than two thirds (69%) of all properties in the 4 cities were considered exempt (primarily because they were single-family, owner-occupied properties), and we were interested in all properties where children might be exposed to lead hazards. Because of inconsistencies in the way rental units were recorded across the databases, we aggregated units to the property level. If a property had more than 1 residential unit, a certificate for at least 1 unit at the property would deem that property as compliant. The date of the first certificate on file was retained and used as the date of compliance because multiple LHMCs could have been obtained during the study.

Analytical Strategy

All analyses were conducted using SAS version 9.3 (SAS Institute, Cary, NC), and all statistical tests were evaluated using an overall significance level of $P < .05$. We first examined property-level compliance with the lead hazard mitigation law over the study period (2005–2009). Then, for nonexempt properties, we assessed which housing characteristics (owner occupancy, residence type, city, and presence of lead-tested children) were associated with compliance. To ascertain the effect of compliance

TABLE 1—Characteristics Associated With Nonexempt Properties Obtaining a Lead Hazard Mitigation Certificate: Central Falls, Pawtucket, Providence, and Woonsocket, RI; 2005–2009

Characteristic	No.	% Compliant
Overall	16 043	20.3
Owner-occupied		
No	14 663	20.7
Yes	1380	16.4
Residence type		
Single-family	3450	8.0
Multifamily	10 018	23.4
Apartment	1346	33.5
Mixed-use	1229	14.7
City		
Central Falls	841	25.8
Pawtucket	2388	20.0
Providence	10 904	19.5
Woonsocket	1910	22.7
One or more lead tests completed, 2005–2009		
No	8054	11.0
Yes	7989	29.7
Residence not occupied by owner		
Single-family	3450	8.0
Multifamily	9120	23.9
Apartment	1225	34.8
Mixed-use	868	16.5
Residence occupied by owner		
Single-family[a]	. . .	. . .
Multifamily	898	18.3
Apartment	121	20.7
Mixed-use	361	10.3

[a]All single-family, owner-occupied properties are exempt (and not included in this table).

with the new legislation on blood lead prevalence, we compared the postcertificate BLLs for children in compliant homes with those for children in noncompliant homes. We also limited our sample to properties with children who had 1 or more lead tests both before and after the property was deemed compliant, and examined the change in BLLs. Finally, we assessed the lead burden in properties that did not obtain an LHMC, because they were either exempt from the regulation or were noncompliant.

RESULTS

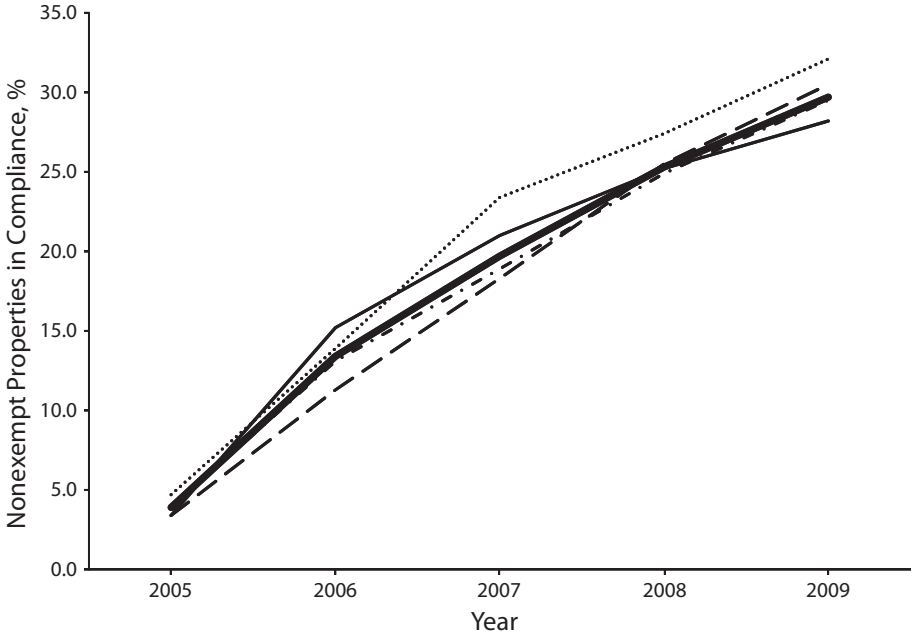
Of the 55 093 properties in the 4 cities, 51 504 were built before 1978. By matching the blood lead data to the property data, we determined that 34.8% (n = 17 944) of these properties had a child with a lead test living there during the study period. Overall, only 10.6% (n = 5467) of the 51 504 properties obtained an LHMC during the study period. However, only nonexempt properties were required to obtain an LHMC. Approximately 70% (68.9%; n = 35 461) of the 51 504 properties in the 4 cities were exempt. Compliance for the exempt properties was optional, resulting in only 6.2% (n = 2212) of these obtaining an LHMC. One fifth (20.3%; n = 3255) of the 16 043 nonexempt properties obtained an LHMC between 2005 and 2009.

As shown in Table 1, compliance rates for the 16 043 nonexempt properties varied significantly by property characteristics. Properties were more likely to obtain an LHMC if they were not owner-occupied (21% vs 16%; $P < .001$). Multifamily, apartment, and mixed-use housing all had higher compliance rates than single-family properties. The municipality-specific compliance rate ranged from 19.5% to 25.8%. Properties with children who had a blood lead test had higher compliance rates than those without children tested (29.7% vs 11.0%; $P < .001$). By examining nonexempt properties where a child has been screened, Figure 1 shows that the proportion of these properties with an LHMC increased annually during the study for all towns. At the start of the study (2005), 3.9% of the properties obtained an LHMC. This increased to 29.7% by 2009, with slight variation across cities, but none seeing more than one third of properties in compliance with the law by the end of 2009.

Effect of Compliance on Lead Levels

We compared blood lead test results for children living in compliant properties (n = 8678 children in 3490 properties) with children living in nonexempt, noncompliant properties (n = 10 122 children in 4853 properties). The mean BLLs were significantly lower in compliant properties than in noncompliant properties (3.3 μg/dL vs 3.5 μg/dL; $P < .001$). There was no significant difference in the percentage of children with a BLL of 5 micrograms per deciliter or greater, but we did find significantly lower rates of children with BLLs of 10 micrograms per deciliter or greater in compliant properties (2.4% vs 4.0%; $P < .001$).

Of the 5467 properties that obtained an LHMC during the study, 16.0% (n = 876 properties) had 1 or more children at the property with blood lead test results before and after obtaining an LHMC (n = 1150 children). The mean BLLs for these children significantly decreased from 5.2 micrograms per deciliter before receiving the certificate to 4.3 micrograms per deciliter after receiving the certificate ($P < .001$). Nearly 40% (39.6%; n = 455) of these children had 1 or more lead tests with a value of 5 micrograms per deciliter or higher before receiving the certificate. After the certificate was issued, 38.2% (n = 174) of these children had all subsequent lead tests with values less than 5 micrograms per deciliter



Central Falls	3.4%	11.3%	18.3%	25.5%	30.5%
Pawtucket	3.4%	15.2%	21.0%	25.2%	28.2%
Providence	3.9%	13.1%	18.9%	24.9%	29.5%
Woonsocket	4.7%	13.9%	23.4%	27.4%	32.1%
All	3.9%	13.4%	19.7%	25.3%	29.7%

FIGURE 1—Lead hazard mitigation conformance for nonexempt properties with resident children aged 0–72 months: Central Falls, Pawtucket, Providence, and Woonsocket, RI; 2005–2009.

in the study period. Fewer than one fifth of these children (17.0%, n = 195) were classified as lead poisoned (BLL ≥ 10 μg/dL) before receiving the certificate. After obtaining the certificate, 44.6% (n = 87) had all subsequent lead tests with values less than 10 micrograms per deciliter.

Lead Burden in Properties Without a Certificate of Conformance

Table 2 presents data on the lead burden for children living in properties that did not have an LHMC at any point during the study. Using the first test result per child per property, there were 25 404 test results used for children residing in 14 159 properties. The mean BLL was 3.3 micrograms per deciliter, with 22.8% having a BLL of 5 micrograms per deciliter or greater. Approximately 1 in 30 children (3.4%) had a blood lead test of 10 micrograms per deciliter or greater. Blood levels were lower for children living in owner-occupied, exempt, and single-family properties. However, even in these properties, the proportion of children with BLLs at or above 5 micrograms per deciliter was substantial for owner-occupied (20.3%), exempt (20.2%), and single-family (17.7%) properties. Even at the level of 10 micrograms per deciliter or greater, elevated lead levels occurred in 2.8% of children in owner-occupied properties, 2.8% in exempt properties, and 2.1% in single-family properties.

DISCUSSION

As stated by the Advisory Committee on Childhood Lead Poisoning Prevention of the CDC, given the clearly documented impact on child health, it is unacceptable to rely only on blood lead screening to identify problem housing after children have already been exposed to lead.[2,9] Enacting and enforcing housing regulations is 1 important approach to primary prevention endorsed by the Advisory Committee. The Rhode Island experience provided support for the importance of healthy housing legislation. After the implementation of the lead hazard mitigation legislation, the proportion of properties with an LHMC rose rapidly during the 5-year study for properties that housed children at risk for lead poisoning. Furthermore, the lead burden was significantly reduced after LHMCs were obtained, demonstrating that LHMCs could have a protective effect for children.

Although our study provided support for the positive impact of legislation, it also clearly demonstrated the limitations and challenges of this approach. Despite the fact that we restricted our analyses to pre-1978 housing in the 4 municipalities at highest risk for lead poisoning in Rhode Island,[6] the majority of properties did not obtain a LHMC during the 5-year study. Even restricting the analysis to properties where a child had been tested for blood lead, no municipality had more than one third of the properties obtaining an LHMC. One important factor in understanding this low proportion was that the majority (68.9%) of properties were exempt from the legislation (this included all owner-occupied properties

TABLE 2—Distribution of Children's Blood Lead Levels for Properties Not Obtaining a Lead Hazard Mitigation Certificate: Central Falls, Pawtucket, Providence, and Woonsocket, RI; 2005–2009

Variable	No.	Mean BLL, μg/dL (95% CI)	Any Test With BLL ≥ 5 μg/dL, %	Any Test With BLL ≥ 10 μg/dL, %
All properties	14 159	3.27 (3.23, 3.32)	22.8	3.4
Owner-occupied				
No	5048	3.58 (3.51, 3.66)	27.3	4.4
Yes	9111	3.10 (3.05, 3.15)	20.3	2.8
Exempt				
No	5617	3.55 (3.48, 3.63)	26.8	4.3
Yes	8542	3.09 (3.03, 3.63)	20.2	2.8
Residence type				
Single-family	4554	2.91 (2.84, 2.99)	17.7	2.1
Multifamily	8807	3.45 (3.40, 3.51)	25.4	4.0
Apartment	506	3.27 (3.08, 3.46)	24.2	3.6
Mixed-use	292	3.40 (3.10, 3.71)	22.9	4.6
City				
Central Falls	1006	3.30 (3.14, 3.45)	23.8	3.4
Pawtucket	3586	2.86 (2.78, 2.93)	17.0	1.8
Providence	7908	3.54 (3.48, 3.61)	26.4	4.4
Woonsocket	1659	2.87 (2.77, 2.97)	17.5	1.8

Note. BLL = blood lead level. The first test per child per property was used to avoid artificially inflating the means because of children with higher lead levels being more likely to have repeated testing over time.

with fewer than 4 units). Although it could be argued that exempt properties were lower risk, they clearly still presented substantial risk—one fifth of tested children living in exempt housing had a blood lead test of 5 micrograms per deciliter or greater. Although there might be legitimate debates about property rights and the recognition of political realities, legislation that does not apply to the majority of properties will not meet the goal of having a primary prevention program to protect children from lead exposure before they are poisoned.

Expanding the scope of legislation to cover all properties could have an important impact because nonexempt properties were significantly more likely to obtain an LHMC. However, as the Rhode Island experience also clearly demonstrated, expanding the scope of the legislation might be necessary, but without strict enforcement, it is insufficient. Even among nonexempt properties in these high-risk communities, only one fifth (20.3%) obtained an LHMC. It is difficult to advocate for expanded legislation when the current legislation is not being widely adopted. Even if municipalities have the will to enforce the regulations, they must also have the resources for active enforcement. Current enforcement activities require tenants to file complaints with the RIHRC. The Rhode Island experience demonstrated that many property owners will not comply with the legislation in the absence of an effective enforcement strategy.

One study limitation was that we did not know whether the properties that did comply with the lead hazard legislation did so to fulfill their legal obligation, or whether it was precipitated by a case of a child becoming lead poisoned at the property. In addition, we did not know the status of individual units in a multifamily property. We made the presumption that an LHMC for a property included all units. It is possible, however, that some of the multifamily properties did not have an LHMC for all units. Finally, we did not know how long children resided at a specific property. There might be children who moved to a new property that was not compliant and had a blood lead test soon after. The lead test results might be from lead exposure at the property they moved from.

The study data suggest that primary prevention is still not the rule, even for properties that obtained an LHMC. The children living in properties before they became compliant had BLLs even above those in properties that never received a lead certificate. The most likely explanation for this is that compliance is not being sought or enforced until after children have already been poisoned.

In summary, our study demonstrates that legislation can dramatically increase the proportion of properties with an LHMC, and when a property is compliant with the law, BLLs can decrease for children living in the property. However, legislation cannot be a highly effective primary prevention strategy if it does not cover all properties where children live. It is critical that all children have a safe environment to foster healthy development. ■

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Contributors

M. L. Rogers conducted the analyses and led the writing. J. A. Lucht developed the study concept and acquired the data. A. J. Sylvaria provided critical revisions to the draft. J. Cigna assisted with developing the study concept and data preparation. R. Vanderslice assisted with developing the study concept. P. M. Vivier critically revised the draft and assisted with interpretation of results. All authors reviewed and approved the final version for submission.

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Human Participant Protection

The study was approved by the Brown University institutional review board.

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