Residential Lead-Based-Paint Hazard Remediation and Soil Lead Abatement: Their Impact among Children with Mildly Elevated Blood Lead Levels

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ABSTRACT

Objectives. This prospective study describes the impact of residential lead-based-paint hazard remediations on children with mildly elevated blood lead levels.

Methods. Changes in blood lead levels were observed following paint hazard remediation alone and in combination with soil abatement.

Results. After adjustment for the confounding variables, paint hazard remediation alone was associated with a blood lead increase of 6.5 μg/dL ($P = .05$), and paint hazard remediation combined with soil abatement was associated with an increase of 0.9 μg/dL ($P = .36$).

Conclusions. Lead-based-paint hazard remediation, as performed in this study, is not an effective secondary prevention strategy among children with mildly elevated blood lead levels. (*Am J Public Health.* 1997;87: 1698–1702)

Introduction

Lead-based-paint hazard remediation can lower blood lead levels among children with starting levels of 25 μg/dL or higher,[1,2] but these results may not apply to children with lower blood lead levels because exposure sources may differ. Currently, however, few data exist on the impact of lead-based-paint hazard remediation on children with only mildly elevated levels.

This report presents the results of Phase II of the Boston Lead-in-Soil Demonstration Project. Phase I evaluated whether lead-contaminated soil abatement reduced children's blood lead levels. Phase II was designed to assess children's blood lead levels and household dust lead levels following (1) lead-based-paint hazard remediation alone and (2) in combination with soil abatement.

Methods

Identification and Enrollment of the Study Population

Enrolled in the study were 152 children with blood lead levels between 7 and 24 μg/dL who were less than 4 years old. Additional eligibility criteria are described elsewhere.[3] During Phase I, children were randomly assigned to three groups. Group 1 received soil and interior dust abatement and interior loose-paint stabilization (n = 54); Group 2, interior dust abatement and interior loose-paint stabilization (n = 51); and Group 3, interior loose-paint stabilization (n = 47). During Phase II, soil abatement was offered to Groups 2 and 3, and residential lead-based-paint hazard remediation was offered to all three groups. Because their Phase II interventions were identical, Groups 2 and 3 were combined (hereafter, Group 2/3).

All children received their assigned Phase I interventions. In Phase II, 93.7% of children in Group 2/3 received soil abatement, and 38.3% in Groups 1 and 2/3 received paint hazard remediation. Refusal and relocation of residence were the primary reasons for not receiving the interventions. By the end of Phase II, 91 of the original 152 children were still participating.

Soil and Dust Abatement, Interior Loose-Paint Stabilization

Soil abatement consisted of removing the top 15 cm of soil from a yard and covering the exposed subsurface with geotextile fabric, 20 cm of clean soil, and ground cover. Interior dust abatement consisted of vacuuming walls, woodwork, floors, and rugs with a high efficiency particulate aerosol (HEPA) filter vacuum, and wiping surfaces with wet cloths and furniture with oil-treated cloths. Interior loose-paint stabilization consisted of HEPA vacuuming and washing areas of loose paint on walls and woodwork with trisodium phosphate, and painting window wells with primer.

Lead-Based-Paint Hazard Remediation

Licensed contractors performed paint hazard remediation that met or exceeded requirements of the Massachusetts Lead Poisoning Prevention and Control Act.[4] Occupants and their belongings were relocated off site during the interior remediations. Remediation was conducted on exterior areas, and inside the

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living unit and common areas of multiunit buildings, if, upon inspection, an x-ray fluorescence reading exceeded 1.2 mg/cm^2 or a sodium sulfide chemical reaction was positive.

Exterior remediation involved removing or covering lead paint from accessible mouthable surfaces 5 feet or less from the ground, and making intact loose paint on all other surfaces, including walls, windows, doors, and stairs. Interior remediation involved removing or covering lead paint from accessible mouthable surfaces 5 feet or less from the floor, and making intact loose paint on all other surfaces in the living unit and common interior areas. When common areas of multiunit buildings were remediated, containment barriers were set up, and HEPA vacuum units were installed at the building entrance.

Remediation methods included dipping items in paint-removing chemicals off site; covering areas with aluminum, plastic caps, or Plexiglas; removing and replacing items; and, when necessary, dry scraping. All treated areas were given a coat of paint primer, and all surfaces were HEPA vacuumed and wet washed, and wood floors were coated with polyurethane.

In accordance with Massachusetts law,[4] reoccupancy was permitted only if dust lead levels in clearance wipe samples were below 200, 500, and 800 µg/ft^2 on floors, window sills, and wells, respectively. Additional cleanups were conducted until criteria were met.

Environmental Measurements and Analysis

Surface soil and household dust samples were taken at baseline and periodically thereafter to monitor the rate of recontamination following the abatements. Soil and dust samples were analyzed by x-ray fluorescence by an Environmental Protection Agency (EPA) laboratory. The detection limits were 100 ppm for each. First-flush water samples were analyzed by means of EPA test method 239.2.

Child Measures

Interviews were conducted with parents after enrollment and at each round of biologic sampling to obtain information on demographic characteristics, sources of lead exposure, mouthing behaviors, play activities and locales, and handwashing practices.

TABLE 1—Characteristics[a] of Study Population according to Group and Phase II Intervention Status: Boston, Mass, 1990 through 1991, Boston Lead-in-Soil Demonstration Project

	Group 1[b]		Group 2/3[b]	
	Paint Hazard Remediation (n = 18)	No Paint Hazard Remediation (n = 13)	Paint Hazard Remediation and Soil Abatement (n = 25)	Soil Abatement Only (n = 31)
Blood lead level, µg/dL, preintervention, mean (range)	10.7 (5–22)	10.8 (6–16)	11.2 (3–20)	11.9 (6–20)
Ferritin level µg/L, preintervention, % ≤15	0.0	50.0	28.0	16.7
Age, mo, preintervention, mean (range)	42.9 (28–62)	43.3 (24–61)	40.6 (23–60)	44.3 (24–58)
Male, %	61.1	69.2	52.0	48.4
Black, %	44.4	46.2	52.0	54.8
White, %	0.0	0.0	16.0	3.2
Hispanic, %	16.7	38.5	8.0	6.5
Cape Verdean, %	38.9	15.4	8.0	22.6
Socioeconomic status, % classes 4, 5[c]	82.4	61.5	56.0	67.7
Owner-occupied home, %	88.9	46.2	96.0	74.2
Lead jobs among household members, %	33.3	30.8	40.0	16.7
Lead hobbies among household members, %	33.3	46.2	52.0	67.7
Water lead levels, µg/L, median	18.0	20.4	23.4	17.0
Soil lead level, ppm, preintervention median	50	50	2300	2100
Floor-dust lead loading, µg/m^2, preintervention geometric mean	18.5	13.5	19.7	20.1
Window-well-dust lead loading, µg/m^2, preintervention geometric mean	2331	4910	1824	2594
No. interior surfaces positive for lead paint, median	28	19	36	24
No. loose interior painted surfaces, median	21	39	64	27
No. exterior surfaces positive for lead paint, median	15	11	16	13
No. loose exterior painted surfaces, median	17	20	28	25

[a]Variables were generally categorized; cutoff points were based on the frequency distributions. Whenever possible, medians were used as cutoff points for continuous variables. However, when the number of subjects was too sparse, categories were created that included at least 20% of subjects.
[b]In Group 1, only paint hazard remediation was conducted during Phase II; soil abatement was conducted during Phase I. In Group 2/3, both paint hazard remediation and soil abatement were conducted during Phase II.
[c]Socioeconomic status as measured by the Hollingshead Index.

TABLE 2—Crude Changes in Blood Lead Levels, Boston, Mass, 1990 through 1991

	Mean Blood Lead Level before Phase II Intervention(s), μg/dL	Mean Blood Lead Level after Phase II Intervention(s), μg/dL	Mean Change in Blood Lead Levels	Difference between Mean Changes, μg/dL (95% CI)
Group 1[a]				+2.6 (−0.6, +5.9)
Lead-based-paint hazard remediation (n = 18)	10.7	11.1	+0.4	...
No lead-based-paint hazard remediation (n = 13)	10.8	8.5	−2.2	...
Group 2/3[a]				+1.4 (−0.7, +3.5)
Lead-based-paint hazard remediation and soil abatement (n = 25)	11.2	9.0	−2.2	...
Soil abatement only (n = 31)	11.9	8.3	−3.6	...

Note. CI = confidence interval.
[a]In Group 1, only paint hazard remediation was conducted during Phase II; soil abatement was conducted during Phase I. In Group 2/3, both paint hazard remediation and soil abatement were conducted during Phase II.

TABLE 3—Adjusted Changes in Blood Lead Levels among Group 1 Children,[a] Boston, Mass, 1990 through 1991

	Adjusted Blood Lead Level after Phase II Interventions, μg/dL			
	Lead-Based-Paint Hazard Remediation	No Lead- Based-Paint Hazard Remediation	Adjusted Difference in Blood Lead Levels, μg/dL	*P*
Base model[b]	11.1	8.5	+2.6	.11
Plus ferritin level[c]	12.4	8.5	+3.9	.07
Plus age	11.2	8.6	+2.6	.11
Plus gender	11.2	8.7	+2.5	.13
Plus race	11.2	8.6	+2.6	.10
Plus socioeconomic status[c]	12.5	9.0	+3.4	.04
Plus owner-occupied premises	11.6	8.5	+3.1	.10
Plus lead jobs	10.9	8.3	+2.6	.11
Plus lead hobbies	11.5	8.6	+2.9	.07
Plus imported canned food intake	11.5	9.0	+2.5	.17
Plus hand washing before meals	11.4	9.4	+2.0	.26
Plus plays on floor inside	11.0	8.5	+2.6	.14
Plus yard play	11.3	8.7	+2.6	.11
Plus time away from home	11.2	8.1	+3.1	.05
Plus mouths items likely lead painted	11.1	8.3	+2.8	.13
Plus water lead level	11.3	8.5	+2.8	.11
Plus soil lead level	11.5	8.4	+3.1	.09
Plus number of lead painted interior surfaces[c]	11.0	7.6	+3.4	.04
Plus number of loose painted interior surfaces[c]	11.0	7.7	+3.3	.04
Plus number of lead-painted exterior surfaces[c]	11.2	7.6	+3.6	.03
Plus number of loose painted exterior surfaces	10.7	7.6	+3.1	.05
Plus baseline floor-dust lead loading (ln)[c]	10.7	9.4	+1.4	.45
Plus baseline window-well lead loading (ln)	11.2	8.4	+2.8	.13
Plus all indicated variables[d]	14.2	7.7	+6.5	.05

[a]In Group 1, only paint hazard remediation was conducted during Phase II; soil abatement was conducted during Phase I. In Group 2/3, both paint hazard remediation and soil abatement were conducted during Phase II.
[b]Base model controls for baseline blood lead level.
[c]These variables were also controlled simultaneously in the multivariate model.
[d]Multivariate model with all indicated variables. Number of lead-painted interior surfaces and number of loose painted surfaces were combined into a single variable.

Children's venous blood lead levels before and after the environmental interventions were determined. During Phase II, the interval between the interventions and follow-up blood sampling averaged 9 months (range: 7 through 11 months). Blood lead levels were measured by means of graphite furnace atomic absorption spectrometry.[5] The detection limit was 1 μg/dL.

Data Analysis

The 91 children with blood lead determinations before and after Phase II interventions were eligible for the analysis. A child was excluded if (1) neither soil abatement nor paint hazard remediation was conducted (n = 1); (2) no lead paint was found inside the home (n = 1); or (3) Phase II postintervention residual blood lead level was more than 3 standard deviations from zero (n = 2). The analysis was based on 87 children. Group 1 consisted of 31 children who received soil abatement during Phase I. Comparisons were made between children who received paint hazard remediation during Phase II (n = 18) and those who did not (n = 13). Group 2/3 consisted of 56 children. Comparisons were made between those who received both paint hazard remediation and soil abatement during Phase II (n = 25) and those who received only soil abatement (n = 31).

Crude analyses were conducted to describe the change in blood lead levels according to group and intervention status. Analysis of covariance was conducted to adjust comparisons of Phase II postintervention blood lead levels for Phase II preintervention blood lead levels.[6] Factors that altered the estimated abatement effect by 0.5 μg/dL or more (Group 2/3) or 0.7 μg/dL or more (Group 1) were considered for multivariate models. (A higher cutoff was used for Group 1 because its sample size was smaller.) Potential confounders included age, sex, race, socioeconomic status, mouthing, hand-washing and play behaviors, housing characteristics, and environmental sources of lead. Floor and window-well-dust lead-loading levels before and after Phase II interventions and housing characteristics were considered potential modifiers of the impact of paint hazard remediation. Natural log transformations were applied to dust lead levels.

TABLE 4—Adjusted Changes in Blood Lead Levels among Group 2/3 Children,[a] Boston, Mass, 1990 through 1991

	Adjusted Blood Lead Level after Phase II Interventions, μg/dL			
	Lead-Based-Paint Hazard Remediation and Soil Abatement	Soil Abatement Only	Adjusted Difference in Blood Lead Levels, μg/dL	*P*
Base model[b]	9.2	8.2	+1.0	.24
Plus ferritin level	8.7	7.5	+1.2	.16
Plus age	9.2	8.2	+1.0	.25
Plus gender	9.2	8.2	+1.0	.25
Plus race	9.2	8.2	+1.0	.25
Plus socioeconomic status	9.1	8.0	+1.1	.18
Plus owner-occupied premises	8.6	7.9	+0.7	.41
Plus lead jobs[c]	9.4	8.9	+0.5	.59
Plus lead hobbies	9.2	8.3	+0.9	.31
Plus imported canned food intake[c]	8.5	8.0	+0.5	.61
Plus hand washing before meals	9.0	8.0	+1.0	.24
Plus plays on floor inside	9.1	8.4	+0.6	.48
Plus yard play	9.1	8.3	+0.8	.31
Plus time away from home	9.3	8.2	+1.1	.21
Plus mouth items likely lead-painted	9.8	8.5	+1.3	.12
Plus water lead level	9.0	8.0	+1.0	.23
Plus soil lead level	9.1	8.2	+0.9	.31
Plus number of lead painted interior surfaces[c]	9.3	7.5	+1.8	.04
Plus number of loose painted interior surfaces[c]	9.2	7.4	+1.8	.04
Plus number of lead-painted exterior surfaces[c]	9.5	7.8	+1.7	.07
Plus number of loose painted exterior surfaces	9.3	7.9	+1.4	.11
Plus baseline floor-dust lead loading (ln)	9.5	8.2	+1.3	.19
Plus baseline window-well lead loading (ln)	9.3	8.4	+1.0	.34
Plus all indicated variables[d]	9.6	8.7	+0.9	.36

[a]In Group 1, only paint hazard remediation was conducted during Phase II; soil abatement was conducted during Phase I. In Group 2/3, both paint hazard remediation and soil abatement were conducted during Phase II.
[b]Base model controls for baseline blood lead level.
[c]These variables were also controlled simultaneously in the multivariate model.
[d]Multivariate model with all indicated variables. Number of lead-painted interior surfaces and number of loose painted surfaces were combined into a single variable.

Results

Children whose homes received paint hazard remediation differed in many respects from those whose homes did not (Table 1). Following Phase II interventions, mean blood lead level of children whose homes received only paint hazard remediation was 2.6 μg/dL higher than that of children whose homes received no Phase II interventions (Group 1). Mean blood lead level of children whose homes received both paint hazard remediation and soil abatement was 1.4 μg/dL higher than that of children whose homes received only soil abatement (Group 2/3, Table 2). The impact of paint hazard remediation was not affected by children's starting blood lead levels (≤10 μg/dL vs >10 μg/dL).

Several variables met the criteria for potential confounders (Tables 3 and 4). When these were controlled simultaneously in multivariate models, the adjusted increase associated with paint hazard remediation was +6.5 μg/dL (*P* = .05) in Group 1 and +0.9 μg/dL (*P* = .36) in Group 2/3.

Group 1 children had a smaller mean blood lead increase following remediation if they lived in homes with a greater number of interior window areas with lead paint (+0.9 vs +4.0) and a larger number of loose exterior painted surfaces (+1.5 vs +4.1). Group 2/3 children had a smaller increase if they resided in homes with a larger number of interior window areas with lead paint (+0.5 vs +3.6), painted interior surfaces with higher lead concentrations (+1.1 vs +3.0), a larger number of loose interior painted surfaces (+0.8 vs +2.7), and more exterior surfaces with lead paint (+0.2 vs +2.4).

Greater declines in blood lead level were associated with a larger number of remediated interior areas (Group 1: −0.8 vs +0.9; Group 2/3: −3.1 vs −0.6), with "removal and replacement" (Group 1: −0.7 vs +2.1; Group 2/3: −3.8 vs −0.4), and with multiple cleanups (Group 1: −0.8 vs +1.3; Group 2/3: −2.7 vs −1.9).

An average of 8 months following the interventions, mean floor-dust lead-loading levels were higher in all groups, but the increase was greatest in homes that received paint hazard remediation (+142% vs +75% in Group 1 and +42% vs +33% in Group 2/3). Mean postabatement window-well-dust lead-loading levels rose (+105% in Group 1) or remained stable (+2% in Group 2/3) in homes that received paint hazard remediation, but declined in homes that did not (−42% in Group 1 and −41% in Group 2/3).

Discussion

Lead-based-paint remediation alone was associated with statistically significant blood lead increase of 6.5 μg/dL over the subsequent 9 months, but with an increase of only 0.9 μg/dL when combined with soil abatement. The beneficial impact of soil abatement may account for the smaller increase when both interventions were conducted. In Phase I, a soil lead reduction of 2060 ppm was associated with a 2.25 to 2.70 μg/dL reduction in blood lead levels.[7] The factors that reduced the detrimental impact of paint hazard remediation cannot be precisely quantified. However, the benefits were greatest when more interior areas were remediated overall, when "removal and replacement" was used, and when multiple cleanups were performed.

Children's blood lead levels increased even though the paint remediation met or exceeded the requirements of Massachusetts law.[4] Dust-generating practices may have been responsible for increasing children's lead exposure. Studies have shown that these methods increase the amount of lead-contaminated dust in the home[8] and the blood levels among resident children.[8,9]

Cleanup and clearance testing procedures may have been inadequate. Single cleanups may not have sufficiently reduced lead-contaminated-dust levels. Some inadequately cleaned homes may have passed the clearance testing. Alternatively, clearance standards may not be sufficiently stringent.

While some studies have shown that paint remediation benefits children with blood lead levels of 25 μg/dL or above,[1,2] this may not be true among children with lower blood lead levels. In our study, increases occurred among children over the entire range of initial blood lead levels (3 through 22 μg/dL). In the only published study among children with starting levels below 20 μg/dL, paint remediation was associated with a 2.5 μg/dL increase in mean blood lead level up to 1 year later.[10]

This study has several limitations. First, participants who received Phase II paint hazard remediations were self-selected, requiring adjustment for many group differences. Second, only 57% of the original population was available for these analyses. Since the demographic characteristics of the initial and final populations were similar, it is unlikely that attrition led to bias. Third, children had aged and had received several environmental and educational interventions by Phase II, thereby lowering starting blood lead levels and possibly biasing the results toward the null.

In summary, lead-based-paint hazard remediation increased the blood lead level of children with initial blood lead levels less than 25 μg/dL, at least within the year following remediation. These findings support current Centers for Disease Control and Prevention recommendations to place greater emphasis on primary prevention, particularly the permanent abatement of residences *before* occupancy, and to prioritize secondary prevention remediations by blood lead level. □

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