

# Occurrence and determinants of increases in blood lead levels in children shortly after lead hazard control activities

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## Abstract

This study is an examination of the effect of lead hazard control strategies on children's blood lead levels immediately after an intervention was conducted as part of the US Department of Housing and Urban Development's Lead-Based Paint Hazard Control Grant Program. Fourteen state and local government grantees participated in the evaluation. The findings indicated an overall average reduction in the blood lead levels of 869 children soon after the implementation of lead hazard controls. However, 9.3% of these children ( $n = 81$ ) had blood lead increases of 5  $\mu\text{g}/\text{dL}$  or more. Data routinely collected as part of the evaluation, as well as additional information supplied by the individual programs, were used to determine potential reasons for these observed increases in blood lead. A logistic regression analysis indicated that three principal factors were associated with the blood lead increases: the number of exterior deteriorations present in the child's home (prior to intervention), the educational level of the female parent or guardian of the child, and the child's age. The statistical analysis did not find evidence that children living in households that either did not relocate or relocated for less than the full work period were significantly more likely to have a blood lead increase equal to or greater than 5  $\mu\text{g}/\text{dL}$  than children living in households that fully relocated. Statistical analyses also did not reveal any single interior strategy to be more or less likely than others to be associated with a blood lead increase of 5  $\mu\text{g}/\text{dL}$  or more.

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## 1. Introduction

The Centers for Disease Control and Prevention (CDC) estimates that 2.2% of US children aged 1–5 years, which corresponds to 434,000 children, have blood lead levels  $\geq 10 \mu\text{g}/\text{dL}$  (95% confidence interval, from 189,000 to 846,000) (CDC, 2003), which is defined as the health concern level for young children (CDC, 1991). As part of its efforts to promote nationwide efforts to reduce lead exposures, the Department of Housing and Urban Development (HUD) has embarked on a long-term program to provide support to local and state governments to develop lead-based paint hazard control grant programs. HUD required the first state and local governments receiving grants under this program to participate in an evaluation of the effective-

ness of the lead hazard control programs. Selected grantees from the second round of grantees were invited to participate. The evaluation of the HUD Lead-Based Paint Hazard Control Grant Program (termed here the Evaluation) is the largest and most comprehensive study of lead hazard control in housing ever undertaken in the United States. Data collection efforts were initiated in 1994 by grant recipients (grantees) from 14 state and local governments across the nation and continued until the fall of 1999. The Evaluation is a cooperative effort of these 14 grantees, the National Center for Healthy Housing, and the University of Cincinnati Department of Environmental Health.

Previous studies revealed that intervention practices common in the 1980s resulted in increases in cases of lead poisoning due to increases in dust lead levels (Farfel and Chisolm, 1990; Amitai et al., 1987). Later research showed that it was possible to perform lead paint hazard control in a manner that resulted in a decrease in dust

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lead levels (Farfel et al., 1994). The HUD Notice of Funding Availability for the first round of the lead hazard control grant program put into place three occupant protection practices: clearance dust testing, workplace containment requirements, and the requirement of temporary relocation of families if the planned lead hazard control work warranted it. In order to reduce the possibility of blood lead increases resulting from the intervention activities conducted by participating grantees in the Evaluation, the Evaluation protocol required strict adherence to HUD lead dust-wipe clearance testing requirements and the establishment of an effective plan for the relocation of residents during lead hazard reduction activities.

One of the initial objectives of the Evaluation was to identify factors that were associated with the significant (i.e.,  $\geq 5 \mu\text{g}/\text{dL}$ ) increases in blood lead levels that occurred between preintervention and clearance. The Evaluation protocol required the collection of a blood sample for lead determination within 6 weeks following completion of the intervention to determine whether a blood lead increase of a child living in housing that had undergone lead hazard control may have resulted from any aspect of the relocation process or from the intervention activities.

This paper presents data on the frequency and magnitude of blood lead increases between preintervention and the first postintervention blood lead testing that was conducted an average of 6.8 weeks after completion of interventions. An assessment was made of factors that were associated with the increases of  $5 \mu\text{g}/\text{dL}$  or more in children's blood lead levels, which occurred shortly after lead hazard control activities were completed. The most commonly conducted lead hazard control work in the Evaluation included the stabilization of paint, the replacement of windows, and the exercise of any lead hazard control treatment on the exterior of the building but not soil treatment. Only about 15% of the buildings in the Evaluation had soil treatments.

## 2. Methods

### 2.1. Blood sample collection and analysis procedures

Blood lead tests were performed on resident children between the ages of 6 months and 6 years whose parents agreed to participate. Attempts were made to acquire blood for lead analysis prior to intervention (within 6 weeks), immediately after intervention, and later periods. Initial findings from the Evaluation showed a marked decrease in blood lead levels that persisted throughout the period of study (Galke et al., 2001). Grantee programs were allowed to substitute the results of a previously collected blood lead sample for the

preintervention sample as long as the program could verify the results through medical records.

Trained phlebotomists obtained blood specimens from participating children, primarily using venipuncture methods. On a case-by-case basis, if a venous sample could not be obtained the phlebotomist could collect a capillary sample instead. Seventy-four percent of all blood samples were collected by venipuncture. For a high percentage of the samples (93%) the same collection method was used for samples collected preintervention and for those collected shortly after intervention.

Each regional program determined their own laboratory (or laboratories) to analyze the blood specimens. Each laboratory was required to meet the proficiency standards set under the Clinical Laboratory Improvement Act of 1988. Lead was measured by either graphite furnace atomic-absorption spectrophotometry or anodic stripping voltametry.

To aid in assessing the ability of laboratories to accurately and reliably measure lead content, grantees had their participating laboratories analyze QC "spike" samples prepared by the CDC. QC results were monitored over time; results that deviated from their true value by more than  $3 \mu\text{g}/\text{dL}$  were considered to be in error. Over the entire period of the Evaluation, only 23 blood samples from two laboratories were excluded from the data set due to poor lab performance. This represents less than 1% of all of the blood lead samples reported. Additional QC information will be available in the final report of the Evaluation of the HUD Lead-Based Paint Hazard Control Program, Appendix B.

Many initial blood lead sample results were reported to be below the reporting limits of certain laboratories. The laboratories were asked to supply the actual machine values for samples with a lead content below reporting limits. When machine values could not be obtained, blood lead values were imputed according to methods delineated in Succop et al. (2004).

### 2.2. Other data collection

Paint lead, using field portable X-ray fluorescence analyzers (XRF), and the condition of painted surfaces were determined at preintervention on about 100 surfaces per dwelling unit. Dust lead levels and the surface condition of floors, windowsills, and window troughs, where the dust-wipe samples were collected, were determined both preintervention and immediately after intervention, the latter data serving as clearance testing following the abatement activities. Floor dust samples were collected from the interior entry to the dwelling unit, doorways in the youngest child's playroom (or living room), that child's bedroom, the bedroom of a second child under 6 years of age (if present), and the kitchen. Interior windowsill samples

were collected from the youngest child's bedroom and the kitchen; window trough samples were collected from the child's playroom and the second child's bedroom.

A child's age, sex, mouthing behavior, and other characteristics and household information such as size, income, and education were determined by interview at both pre- and postintervention. Preintervention building and dwelling unit conditions, living space, and entry height were determined by visual inspection.

Grantees were encouraged to try a variety of intervention strategies to meet local conditions and needs. These strategies were categorized as interior, exterior, and site interventions. Details on the relocations of families, such as the length of relocation, the location of relocated housing, and whether any family members returned to the house during intervention, were obtained through an interview with the family.

More details on intervention strategies and other features of the Evaluation have been published elsewhere (Galke et al., 2001).

### 2.3. Survey of grantees

Grantees were requested to complete a survey designed to obtain additional information on possible reasons why a given child would have experienced a 5 µg/dL or more increase in his or her blood lead level from preintervention to immediately postintervention. Grantees were asked to review their programmatic files and then use their professional judgment to speculate why that particular child could have manifested the increase in his or her blood lead. A checklist was developed to assist grantees in this process. Responses from grantees were recorded using nine initial categories of possible reasons for blood lead increases, including "other" and "unknown."

### 2.4. Children excluded from analysis

Although both pre- and immediate postintervention blood lead data were available for 869 children, 216 children were excluded from further analysis because the data for these children did not meet the basic study requirements or the children lived in dwellings where an intervention strategy occurred in less than 10 dwellings. The analytic data set therefore contained 653 children. In the total population of children with both pre- and postintervention blood lead data, there were 81 whose blood lead levels increased by 5 µg/dL during this interval. Among the children excluded, there were 12 children (6%) with blood lead increases of 5 µg/dL or more. This percentage was significantly different from the 11% of children (68) within the group of 653 children who were included in the analytic data set ( $P = 0.03$ ). Following are the number of children whose data did not meet specific study criteria (some may have missed more than one data item): the child was outside the age range of 6–72 months, 43; the preintervention blood sample was collected earlier than 16 weeks prior to the intervention or more than 4 weeks after start of the intervention, 164; fewer than 10 houses had a specified type of intervention, 60; and the child was missing one or more variables found to be significant in statistical analyses: 74 (Table 1).

### 2.5. Statistical analysis methods

A repeated-measure (preintervention and immediate postintervention data) logistic regression using the generalized estimating equation was used to identify factors in the analytic data set that were statistically associated with the immediate postintervention blood lead increases. A complete list of the variables included

Table 1  
Reasons for children being excluded from statistical analysis

Criterion	Number of children not missing information on significant variables		Number of children missing information on significant variables		Total number children
	With increases	Without increase	With increases	Without increase	
Children between 6 and 72 months of age	80	746	1	42	869
Preintervention blood samples collected within –16 to 4 weeks of start date of intervention	70	635	11	153	869
Number of interior strategy > 10	81	728	0	60	869
Missing information of significant variables	80	715	1	73	869
All criteria combined	69	584	12	204	869

81 in full data set.

788 in full data set.

in the analysis is presented in Appendix A. Variables were considered significant at a  $P$ -value of 0.05. Children whose data met the study conditions (including residing in housing that passed clearance after intervention, dust and blood lead data available for both times, type of intervention adequately documented, age of child, educational level and income of parents, date of sample collection) were used in the statistical analysis. The modeling process started with the full model, which included all of the variables listed in Appendix A. Variables were dropped using the backward elimination procedure. After all insignificant variables were dropped from the model, a forward inclusion process was used to develop the final model. If variables that were dropped in the backward elimination process were now found to be significant, they were added to the model. Although the investigators made the decision to examine a very large group of variables in this study, and in others using the Evaluation data, the statistical procedures used were appropriate.

### 3. Results

#### 3.1. Comparisons of children excluded from and those included in the analytic data set

The number of children in the total and analytic data sets described under Methods are presented in Table 2 by grantee and according to whether or not the blood lead increase was  $5\mu\text{g/dL}$  or more. The percentage of children with increases of  $\geq 5\mu\text{g/dL}$  varied by grantee, with a low of 0% (three grantees) and a high of 15.8% (one grantee). For the children with increases of  $5\mu\text{g/dL}$

or more, the average increase in blood lead from pre- to postintervention was  $8.2\mu\text{g/dL}$  for the children in the analytical data set and  $9.8\mu\text{g/dL}$  for those not included; these results were not significantly different ( $P = 0.23$ ). Selected social, environmental, and other variables for these two populations (Table 3) are similar for these two groups, with significant differences only for age, number of exterior deteriorations, and blood collection method, with children in the analytic data set having a lower median age (40 vs. 46 months), fewer blood lead samples collected by the fingerstick method at both time periods (29.7% vs. 35.3%, respectively), and fewer houses with two or more exterior deteriorations (14.6% vs. 25.2%, respectively).

#### 3.2. Survey of grantees

Responses from grantees to the survey were divided into 11 categories of possible reasons for blood lead increases, including other and unknown. A total of 163 responses from grantees were received for the 81 children with pre- to postintervention blood lead increases of  $5\mu\text{g/dL}$  or more (more than one category could be noted for each child) (Table 4). Most of the grantee-provided responses were consistent with the other available data (e.g., month of blood sample collection, child's age). For 8 of the children from one grantee, additional blood lead data provided by the grantee revealed that the blood lead values of these children exhibited a sample-to-sample variation in excess of  $5\mu\text{g/dL}$  prior to the intervention that also appeared subsequent to the intervention. Following a review of information provided by grantees both during the regular data collection and from the special survey,

Table 2  
Distribution of children with and without pre- to postintervention increases of  $\geq 5\mu\text{g/dL}$  in blood lead by grantee

Grantee no.	Number of children with increases	Number of children without increases	Total number of children
01	0(0)	17(13)	17(13)
02	5(5)	61(54)	66(59)
03	2(1)	34(26)	36(27)
04	0(0)	27(18)	27(18)
05	15(14)	87(43)	102(57)
06	9(9)	52(46)	61(55)
07	19(19)	101(83)	120(102)
08	0(0)	0(0)	0(0)
09	3(3)	42(39)	45(42)
10	4(4)	126(91)	130(95)
11	20(11)	150(103)	170(114)
12	2(2)	46(32)	48(34)
13	0(0)	20(18)	20(18)
14	2(1)	25(18)	27(19)
Total	81(69)	788(584)	869(653)

Numbers in parenthesis refer to subset of children in the statistical modeling.

Table 3  
 Characteristics of children with pre- and postintervention blood lead increases  $\geq 5 \mu\text{g/dL}$  excluded and included in the statistical analysis

Characteristics	Children excluded from the analytic data set		Children included in the analytic data set					
	GM	GSTD	GM	GSTD				
Preintervention blood lead ( $\mu\text{g/dL}$ )	10.2	2.07	9.3	2.05				
Postintervention blood lead ( $\mu\text{g/dL}$ )	9.1	1.97	9.3	2.02				
Age (months) <sup>a,*</sup>	5th percentile	Median	95th percentile	5th percentile	Median	95th percentile		
Window paint Pb (mg/sq cm)	11	46	78	13	40	67		
	0	1.2	2.7	0	1.4	2.7		
	$\geq \text{HS}^a$	$\leq \text{HS}$	$\geq \text{HS}$	$< \text{HS}$				
	(%)		(%)					
Education of female parent	57.4	39.4	61.6	35.8				
	0	1	2	0	1	2		
		(%)			(%)			
Number of exterior deteriorations <sup>b,**</sup>	57.3	17.5	25.2	65.2	20.2	14.6		
	02	03	04	05	02	03	04	05
			(%)				(%)	
Interior strategy	7.3	11.4	36.6	40.9	9.8	12.4	27.7	50.1
	F–F	F–V	V–F	V–V	F–F	F–V	V–F	V–V
			(%)				(%)	
Blood collection method <sup>1b,***</sup>	35.3	0.5	1.1	63.2	29.7	3.8	3.5	63.1

GM, geometric mean; GSTD, geometric standard deviation.

<sup>a</sup> HS, high school.

<sup>b</sup> F, fingerstick collection method; V, venipuncture method. The first letter refers to preintervention sample and the second to the postintervention sample.

\*  $P < 0.001$ .

\*\*  $P = 0.002$ .

\*\*\*  $P = -0.02$ .

Table 4  
Summary of responses to grantee survey of possible reasons for pre- to postintervention blood lead increases  $\geq 5 \mu\text{g}/\text{dL}$  (81 children)

Possible reason for blood lead increase	Frequency <sup>a</sup>
Expected seasonal variation	29
Sources of lead in other house(s) (sitter, relative, neighborhood, etc.)	28
Household activities +	21
Hand-to-mouth activity (excessive)	14 <sup>b</sup>
Expected increase due to child's age	10
Job exposure of household member and/or household activities +	7
Unabated exterior lead source	7 <sup>b</sup>
Activities in neighborhood (demolition, industrial, or other)	1
Use of traditional or folk remedies or food/ beverage containers containing lead	0
Other	28
Unknown	18

<sup>a</sup> Multiple reasons can be provided for an individual child.

<sup>b</sup> Responses written in by grantees.

including responses noted in the other category, it appears that 9 children may have had an elevated blood lead related to the lead hazard control work conducted (three cases from one grantee, four cases from another, and 1 each from two other grantees). For each of the 9 children there was information indicating that one of the following situations occurred: the family did not relocate during the intervention (eight cases), the family was present, or one or more family members visited the home while the intervention was underway (one case).

### 3.3. Distribution of blood lead increases

Blood lead increases ranged from 5 to 25  $\mu\text{g}/\text{dL}$  from preintervention to the first postintervention blood sample collected (Fig. 1). A distribution of the blood lead increases for all children with an increase of  $\geq 5 \mu\text{g}/\text{dL}$  is shown in Fig. 1. The average increase was 8.4  $\mu\text{g}/\text{dL}$  for these children, while the average increase for all children included in the logistic regression was 8.2  $\mu\text{g}/\text{dL}$ . Five grantees each had five or more cases in which the children's blood lead exhibited such changes (Table 2).

### 3.4. Results of statistical analyses

The results of the logistic regression analyses of the analytic data set are presented in Table 5. Four factors were significantly associated with blood increases (of 5  $\mu\text{g}/\text{dL}$  or more)

- (i) Child's age at pre-intervention.
- (ii) Female caregiver's education.

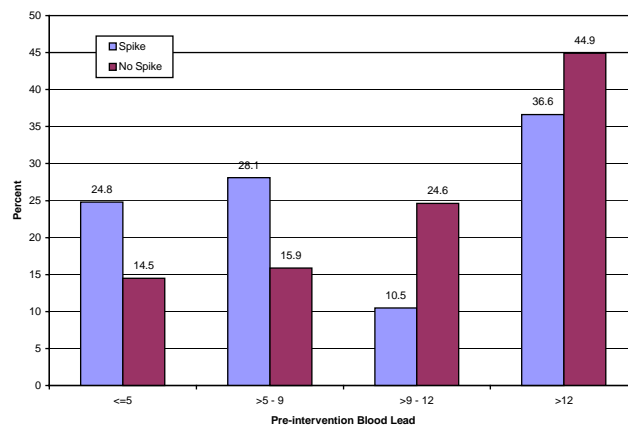


Fig. 1. Distribution of preintervention blood lead levels ( $\mu\text{g}/\text{dL}$ ) for children in the model with an increased of 5 or more compared to those without such increases.

- (iii) General exterior building condition.
- (iv) Season of blood (Phase 02) sample collection.

As the child's age increased, both the odds ratio and the probability of a child showing an increase of 5  $\mu\text{g}/\text{dL}$  or more decreased sharply (Table 6). The age relationship includes a significant quadratic as well as cubic term. For a child 6 months of age, the likelihood of an increase of 5  $\mu\text{g}/\text{dL}$  or more was found to be 168 times higher than for a child 40 months of age; for a child 12 months of age, the likelihood was 52 times higher than at age 40 months. In families in which the female parent had less than a high school education, the likelihood of a 5  $\mu\text{g}/\text{dL}$  or larger blood lead increases was 2.5 times higher than one in which her level of the education was more than high school. As the number of exterior deteriorations increased, the odds ratio for a 5  $\mu\text{g}/\text{dL}$  or more increase in the blood lead level was 1.5 and 2.3 for one exterior deterioration and two or more deteriorations, respectively. A significant effect of season was detected ( $P < 0.005$ ). For example, samples collected on July 15 were 5.3 times more likely to represent an increase of 5  $\mu\text{g}/\text{dL}$  or more than those collected on January 15th; those collected on April 15 and October 15 were, respectively, 2.5 and 2.1 times more likely to represent such an increase, again compared with January 15. The odds ratios and the predicted probability of a child having a blood lead increase of 5  $\mu\text{g}/\text{dL}$  or higher are presented in Table 6. The usual dependency on previously determined blood lead levels was not found in this analysis. The preintervention blood lead was higher for the children who did not exhibit a 5  $\mu\text{g}/\text{dL}$  increase in blood lead from pre- to postintervention than for those of children who did. Factors associated with the intervention, such as the type of strategy, were not found to be predictive of blood lead increases of 5  $\mu\text{g}/\text{dL}$  or more.

Table 5  
Logistic regression model for blood lead increases of  $\geq 5 \mu\text{g}/\text{dL}$

Parameter	DF	Estimate	Standard error	$\chi^2$	Pr > $\chi^2$
Intercept	1	1.6321	1.2747	1.64	0.2004
Age	1	-0.3325	0.1213	7.52	0.0061
Age <sup>2</sup>	1	0.0081	0.0035	5.34	0.0208
Age <sup>3</sup>	1	-0.0001	0.0000	4.45	0.0348
Education—unknown	1	0.0525	0.6998	0.01	0.9401
Education $\geq$ HS <sup>a</sup>	1	-1.1014	0.2915	14.28	0.0002
Education < HS <sup>a</sup>	0	0.0000	0.0000	—	—
Season (sine)	1	0.0111	0.1947	0.00	0.9547
Season (cosine)	1	-0.9021	0.2226	16.42	<0.0001
Number of exterior deterioration	1	0.4753	0.1765	7.25	0.0071
Paint lead on windows	1	0.2620	0.1487	3.11	0.0780
Interior strategy 02	1	-0.5266	0.5972	0.78	0.3779
Interior strategy 03	1	-0.3322	0.5348	0.39	0.5345
Interior strategy 04	1	0.7688	0.3012	6.51	0.0107
Interior strategy 05	0	0.0000	0.0000	—	—

<sup>a</sup> HS, high school.

Table 6  
Predicted odds ratios and probabilities of a child having a blood lead increase  $\geq 5 \mu\text{g}/\text{dL}$  based on the results from the logistic regression model

Variable	Odds ratio of a child having a blood lead increase $\geq 5 \mu\text{g}/\text{dL}$	95% confidence interval	Predicted probability of a child having a blood lead increase $\geq 5 \mu\text{g}/\text{dL}$
Child's age (months) <sup>a</sup>			
6	11.18	2.8–44.16	0.0006
12	3.69	1.68–8.09	0.0011
18	1.79	1.07–2.99	0.0271
24	1.18	0.79–1.76	0.4225
30	0.98	0.74–1.31	0.9099
36	0.96	0.85–1.09	0.5559
42	1.03	0.96–1.10	0.4300
48	1.11	0.85–1.43	0.4433
54	1.12	0.71–1.75	0.6222
60	0.99	0.50–1.94	0.9677
66	0.70	0.24–2.02	0.5116
72	0.38	0.07–2.05	0.2582
Female education			
Less than high school <sup>b</sup>	2.46	1.27–4.74	0.0076
Exterior deterioration			
One exterior element with deterioration <sup>c</sup>	1.51	1.0–2.29	0.0522
Two or more exterior elements with deterioration <sup>c</sup>	2.28	0.99–5.28	0.0522

<sup>a</sup> Odds ratio compared to a child of age 40 months (median) at preintervention.

<sup>b</sup> Odds ratio compared to more than a high school education.

<sup>c</sup> Odds ratio compared to no exterior deterioration (modal).

#### 4. Discussion

There are well-recognized reasons for blood lead levels in children, in particular the age of the child and the season of blood collection. These two variables were found to be significantly associated with blood lead increases of  $5 \mu\text{g}/\text{dL}$ , but, interestingly, no factors associated with the lead hazard control intervention

were significant. In analyses of the Evaluation data set, prior blood lead was found to be a strong indicator of later blood lead level, as has been found in many other populations (Galke et al., 1999). Prior blood lead level was, however, not found to be a significant predictor of blood lead increases of  $5 \mu\text{g}/\text{dL}$  in the current study of a subset of the Evaluation data.

Of the three variables that were found to be different between the analytic data set and those excluded, two of the factors—the number of exterior deteriorations and the blood lead collection method—were not found to be significant predictors of blood lead increases of  $\geq 5 \mu\text{g}/\text{dL}$ . Thus, it is unlikely that the results would have been different if these data had been included.

In a previous study of children whose homes had undergone the “traditional” form of lead abatement that was common in the early 1980s and earlier, over one-half of the children exhibited significant increases in blood lead which was probably related to the dust lead levels that also increased (Farfel and Chisolm, 1990). In the current study, where stringent postintervention clean-up standards were applied, only 81 of the 869 (9.3%) children who had both preintervention and immediate postintervention blood lead samples had blood lead increases equal to or greater than  $5 \mu\text{g}/\text{dL}$  between the two measurements. Less than complete use of occupant relocation procedures was reported for 34% of the children who did not exhibit an increase in blood lead of  $5 \mu\text{g}/\text{dL}$  or more compared to 43% of the 81 children with such increases, which did not reach a statistically significant difference ( $P = 0.08$ ). Interestingly, previous blood lead level was not associated with blood lead increases of  $5 \mu\text{g}/\text{dL}$  or more, as was shown in Table 6. In analyses of the Evaluation data set, prior blood lead is a strong indicator of later blood lead level, as has been found in many other populations (Galke et al., 1999).

## 5. Conclusions

Eighty-one of the 869 children included in this study exhibited a blood lead increase of  $5 \mu\text{g}/\text{dL}$  or more from pre- to postintervention. These blood lead increases ranged from 5 to  $25 \mu\text{g}/\text{dL}$ , with the average increase being  $8.4 \mu\text{g}/\text{dL}$ . Preintervention blood levels for the children who exhibited a  $5 \mu\text{g}/\text{dL}$  or more increase were lower than those for children who did not. A review of responses from the grantees regarding possible reasons for the increases indicates that for as many as 9 (1.0%) of the children, factors related to the intervention may have been involved in the blood lead increases observed. However, statistical analyses of the analytic data set meeting study criteria did not reveal that any intervention-related parameters were significantly related to blood lead increases of  $\geq 5 \mu\text{g}/\text{dL}$ . The factors that were related to the increases were age of child and season, factors often found to be related to blood lead changes, and two other factors: the level of education of the female parent and the number of preintervention exterior deteriorations of the dwelling. The age of the child was found to be the factor having the largest influence. The younger children had the highest like-

lihood of experiencing a blood lead increase. Compared to a 40-month child, the likelihood of increases for children of 6, 12, 24, and 36 months of age was 168, 52, 10, and 2.0, respectively.

## 6. Uncited references

Fifth Interim Report for the Evaluation of HUD Lead-Based Paint Control Grant Program.

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## Appendix A. List of variables used in blood lead increase model

### A.1. Lead hazards

Preintervention (Phase 01) variables:

Entryway dust lead ( $\mu\text{g}/\text{ft}^2$ ) [arithmetic mean (AM)]  
 Surface type of entry floor (hard, painted, or carpet)  
 Surface condition of entry floor (1, good; 2, fair; 3, poor)  
 Average floor surface condition  
 Interior floor dust lead ( $\mu\text{g}/\text{ft}^2$ ) (AM)  
 Percentage of painted floors  
 Percentage of hard floors  
 Percentage of carpeted floors  
 Percentage of painted floors\*average condition of painted floors (AM; 1, good; 2, fair; 3, poor)



Percentage of carpeted floors\*average condition of carpeted floors (AM; 1, good; 2, fair; 3, poor)  
 Percentage of hard floors\*average condition of hard floors (AM; 1, good; 2, fair; 3, poor)  
 Windowsill dust lead ( $\mu\text{g}/\text{ft}^2$ ) (AM)  
 Surface condition of windowsills (AM; 1, good; 2, fair; 3, poor)  
 Percentage painted windowsills  
 Window trough dust lead ( $\mu\text{g}/\text{ft}^2$ ) (AM)  
 Surface condition of window troughs (AM; 1, good; 2, fair; 3, poor)  
 Percentage painted window troughs  
 Percentage dust collected in same room for each component (entries, floors, windowsills, window troughs)  
 Paint lead on interior doors/trims ( $\text{mg}/\text{cm}^2$ ) (AM of log (XRF))  
 Paint lead on interior and exterior windows ( $\text{mg}/\text{cm}^2$ ) (AM of log (XRF))  
 Paint lead on exterior other components ( $\text{mg}/\text{cm}^2$ ) (AM of log (XRF))  
 Paint condition of interior doors/trims (AM; 1, good; 2, fair; 3, poor)  
 Paint condition of interior and exterior windows (AM; 1, good; 2, fair; 3, poor)  
 Paint condition of exterior other components (AM; 1, good; 2, fair; 3, poor)

Interaction between paint lead and condition for each component (interior doors/trims, interior/exterior windows, other interior components, other exterior components).

Interaction between percentage dust collected in same room and dust levels (Phase 01) for each components (entries, floors, windowsills, window troughs).

Interaction of surface type and condition of entry floor  
 Interaction between floor dust lead (Phase 01) and interior strategy  
 Interaction between entry dust lead (Phase 01) and interior strategy  
 Interaction between windowsill dust lead (Phase 01) and interior strategy  
 Interaction between window trough dust lead (Phase 01) and interior strategy  
 Interaction of entry condition and interior strategy  
 Interaction of average floor surface condition (Phase 01) and interior strategy  
 Interaction between surface condition of windowsills and interior strategy  
 Interaction between surface condition of window troughs and interior strategy  
 Interaction between paint lead on interior doors/trims and interior strategy  
 Interaction between paint lead on interior and exterior windows and interior strategy

Interaction between paint lead on exterior other and exterior strategy

Immediate postintervention (Phase 02) variables:

Entryway dust lead ( $\mu\text{g}/\text{ft}^2$ ) (AM)  
 Surface condition of entry floor (1, good; 2, fair; 3, poor)  
 Interior floor dust lead ( $\mu\text{g}/\text{ft}^2$ ) (AM)  
 Surface condition of floor (1, good; 2, fair; 3, poor)  
 Windowsill dust lead ( $\mu\text{g}/\text{ft}^2$ ) (AM)  
 Window trough dust lead ( $\mu\text{g}/\text{ft}^2$ ) (AM)  
 Surface condition of windowsills (AM; 1, good; 2, fair; 3, Poor)  
 Surface condition of window troughs (AM; 1, good; 2, fair; 3, poor)

Preintervention building/dwelling condition

Number of interior elements with deterioration (0, 1, 2) (excluding roof leak and plumbing leak)  
 Roof Leak (0, No; 1, Yes)  
 Plumbing leak (0, No; 1, Yes)  
 Number of exterior elements with deterioration (0, 1, 2, 3, 4, 5) (excluding chimney deterioration)  
 Interaction between number of exterior elements with deterioration and interior strategy  
 Interaction between number of interior elements with deterioration and interior strategy  
 Living space of dwelling at preintervention (sq. ft)  
 Entry height, in stories  
 Market value

#### A.2. Household characteristics

Preintervention (Phase 01) variables:

Was home renovated (0, No; 1, Yes)  
 Years of education of female parent  
 Presence of cleaning equipment (percentage Yes of Question 16 (Q16) in form 04)  
 Frequency of cleaning the house (AM of Q17 in form 04)  
 Frequency of washing exterior windowsills  
 Cleanliness of the home (1, appears clean; 2, some evidence of house cleaning; 3, no evidence of house cleaning)  
 Household income (dollars)  
 Number of children less than 6 years  
 Number of people between 6 and 18 years  
 Number of people in home

#### A.3. Child characteristics

Child's blood lead level ( $\mu\text{g}/\text{dL}$ ) (Phase 01)  
 Child's blood lead level ( $\mu\text{g}/\text{dL}$ ) (Phase 04)

Indicator of blood samples collected up to 16 weeks before start of intervention (Yes, from 0 to 4 weeks after start of intervention; No, up to 16 weeks prior to start of intervention)

Child's age (Phase 01), age square, age cubic

Race of child

Sex of child

Frequency of putting fingers into mouth (Phase 01)

Frequency of putting toys into mouth (Phase 01)

Number of hours awake per week (Phase 01)

Number of hours away from home per week (Phase 01)

Number of hours inside the house per week (Phase 01)

Number of hours outside the house per week (Phase 01)

Parent reports previous poisoning

Child lead interaction between blood lead (Phase 01) and age, age<sup>2</sup>, age<sup>3</sup> (Phase 01)

Child received WIC benefit (0, No; 1, Yes) (Phase 01)

Relocation during intervention

Interaction between entry dust lead (Phase 01) and mouthing behavior

Interaction between interior floor dust lead (Phase 01) and mouthing behavior

Interaction between mouthing behavior and age, age<sup>2</sup>, age<sup>3</sup> (Phase 01)

Interaction between blood lead (Phase 01) and interior strategy

#### A.4. Intervention

Interior strategy

Exterior strategy (0 or work started after the phase being analyzed, no work; 01–05, work)

Site strategy (0 or work started after the phase being analyzed, no work; 01–05, Work)

Interaction between interior strategy and exterior strategy

Interaction between interior strategy and site strategy

#### A.5. Other characteristics

Season of blood sample collection (Phase 01)

Season of blood sample collection (Phase 02)

Season of dust sample collection (Phase 01)

Season of dust sample collection (Phase 02)

Building type (Single unit, 2–4 units, >4 units)

House age

Occupancy status (Phase 01)

Ownership (1, rented; 2, owner occupied; 3, other)

Phase\*\*\*\*

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