A Coordinated Relocation Strategy for Enhancing Case Management of Lead Poisoned Children: Outcomes and Costs

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ABSTRACT *Controlling residential lead hazards is critical for case management of lead poisoned children. To attain this goal, permanent relocation of the family is sometimes necessary or advisable for many reasons, including poor housing conditions; extensive lead hazards; lack of abatement resources, landlord compliance and local enforcement capacity; and family eviction. During 1996–1998, the Kennedy Krieger Institute implemented a unique capitated Program for case management of Baltimore City children with blood lead concentrations (PbB) >19 µg/dL. The Program provided financial, housing, and social work assistance to facilitate relocation as a means of providing safer housing. Nearly half of the Program families relocated with direct assistance, and 28% relocated on their own. The Program evaluation examined the costs and benefits of relocation. Average relocation cost per child was relatively inexpensive (<\$1,500). Average relocation time of 5 months (range <2 months to >12 months) was less than the 8-month average time to complete lead hazard control work in 14 city and state programs funded by U.S. HUD. Relocation was associated with (1) a statistically significant decrease in dust lead loadings on floors, windowsills and window troughs that persisted for one year, and (2) statistically significantly greater decreases in children's PbB compared to children who did not relocate from untreated homes. Children relocated to housing that met current Federal residential dust lead standards had statistically significant decreases in blood lead levels. Visual inspection did not consistently identify relocation houses with dust lead levels below current Federal standards, indicating that dust testing should be an essential component of future programs. This will require additional resources for dust testing and possibly cleaning and repairs but is expected to yield additional benefits for children. The findings support recent U.S. CDC case management recommendations suggesting that permanent relocation to safer housing is a viable means to reduce children's lead exposure. The benefits of relocation notwithstanding, 40% of families moved at least twice. Research is needed to better understand how to expedite relocation and encourage families to remain in safe housing. Relocation does not negate owners' and health authorities' responsibilities to address lead hazards in the child's original house in order to protect future occupants.*

KEYWORDS *Childhood lead poisoning, Case management, Relocation, Lead dust loading, Lead interventions, Elevated blood lead level.*

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INTRODUCTION

The Kennedy Krieger Institute's (KKI) Lead Poisoning Prevention and Treatment Program (the Program) located in Baltimore, Maryland has served as a referral center for the treatment of lead poisoned children since the mid-1970s. For decades, Dr. Julian Chisolm Jr., the Program's Director, had recognized that reducing children's exposure to lead in their homes was the most important factor in preventing and managing childhood lead poisoning.^{1,2} He also recognized that relocation was often the only option for families with lead poisoned children living in dilapidated rental housing with lead paint hazards. Relocation expenses, however, could prevent a low-income family from relocating to safer housing and historically have not been covered by state Medicaid programs or private insurers.

To address this problem, KKI proposed a unique contract program for case management that allowed clinical dollars to be used in a flexible manner for a constellation of housing, social work, educational and relocation services in addition to medical care. During 1995–1998, the Maryland Medicaid agency, Medicaid HMOs and other private insurers agreed to fund a flexible and comprehensive case management program in which KKI was allocated a fixed annual fee per child based on the child's blood lead concentration as described elsewhere.^{3–5}

KKI's contract program was designed to reduce children's exposure to lead and thereby prevent further increases in blood lead concentration and the need for first time or additional inpatient chelation therapy. Major emphasis was placed on providing housing relocation services to families as a means of reducing exposure to lead dust and other lead paint hazards in the home. KKI assumed financial responsibility for each child's lead-related medical care, including any chelation therapy needed during the contract year. Contract children who needed chelation therapy were treated in a residential treatment house located across the street from KKI. This daycare-like setting was developed as a lower cost, family-friendly alternative to inpatient chelation therapy. The Program did not substitute for, or replace, the follow-up and environmental services provided by the local health department for children with elevated blood lead concentrations.

A multi-disciplinary team comprised of social workers, housing assessors, a housing resources coordinator, and the Program director provided assistance to families. The Program assessed the needs of each individual family and developed a plan for safe housing for each affected child. Although emphasized, relocation was not practical or necessary for every family.

Social workers conducted standardized psychosocial assessments focused on the family's financial status, history of payment of rent and utilities, involvement with other social service agencies and availability of social support systems. Based on this assessment, social workers assisted families in identifying their housing goals and developing an appropriate plan. When relocation was desired, social workers used pre-established working relationships with prospective landlords to link families with community resources and arranged for family transportation to visit prospective relocation homes.

The housing resources coordinator identified a pool of rental homes suitable for families and maintained contacts with prospective landlords willing to rent to families with lead poisoned children. Trained housing assessors visually inspected candidate homes to ensure that they met Program criteria for lead safety based on housing condition: intact paint, smooth and easily cleanable floors, and replacement windows or older windows in good condition.

The Program was evaluated by the National Center for Healthy Housing (formerly the National Center for Lead Safe Housing) to examine the costs and benefits of relocation, including changes in blood lead concentrations and dust lead loadings. Because this was an evaluation of an ongoing program, it was not possible to have a randomized study design.

METHODS

Evaluation Overview

We performed longitudinal dust lead testing in the homes of enrolled children in order to assess changes in dust lead outcomes associated with relocation to houses that met KKI relocation criteria. For comparison purposes, we also tested the homes of children who did not relocate. The reader should be aware that this aspect of the evaluation was complicated by the fact that many families moved on their own without KKI assistance or KKI advance knowledge of the move. Additionally, many families moved multiple times during the course of the study. Our data include dust lead data on 88 houses at the time of enrollment.

We analyzed the program's blood lead data on enrolled children in order to assess changes in blood lead concentrations associated with case management with and without relocation. Unfortunately, the blood lead data at one-year post-enrollment were not collected as frequently as originally anticipated. This and the unexpectedly high frequency of multiple relocations limited our ability to examine blood lead changes over time. When a family had multiple enrolled children, data from the youngest child were included in the analysis. Despite the limitations, we present an analysis of blood lead changes at one year by relocation category for 41 children who had no history of chelation therapy.

Recruitment

Children in the Program were eligible for enrollment in the evaluation if they were aged 6 years or less, had a blood lead concentration (PbB) >19 $\mu\text{g/dL}$ and were in a family that had not previously participated in the contract Program or any other KKI lead study. Of the 149 children placed under the contract between November 1995 and August 1997, 126 were eligible for the evaluation. Ninety-seven percent (97%) of eligible children ($n = 122$) were enrolled. Ten of the 112 participating families had two study children, resulting in a total of 112 study families and 122 study children (see Chart 1 for flowchart).

Evaluation follow-up ended when families completed a year of residence at a particular home or when the evaluation ended (May 1998). Many families did not complete a year of residence in any home due to one or more moves during the evaluation period. Informed consent was obtained using forms approved by the Joint Commission on Clinical Investigation, Johns Hopkins Medical Institutions.

Relocation

Families who completed relocations facilitated by the Program ("Kennedy" Relocation) received direct and indirect Program assistance. Direct relocation assistance consisted of any or all of the following: social worker liaison between

CHART 1. KKI study recruitment.

family and prospective landlords, visual inspection of the prospective house by the housing assessor, transportation to visit prospective relocation houses, and small cash outlays for security deposits and rental application fees. Indirect Program relocation assistance included: in-home and in-clinic education about childhood lead poisoning, a visual inspection of the child's home, an in-home cleaning demonstration, a thorough explanation of potential lead hazards identified during the visual inspection, access to a Program social worker, and provision of a list of candidate relocation houses developed by the Program's Housing Resources Coordinator. Families that relocated on their own initiative ("Family" Relocation) received only indirect assistance from the Program.

Dust

Dust wipe samples were collected in the family's home at the time of study enrollment (baseline) and at 6 months and 12 months after baseline for families that did not move. Dust was collected after each relocation as soon as the family notified the Program of their move and, when possible, 6 and 12 months after the move. For Kennedy relocations, dust samples were usually collected within 2 weeks of relocation. Dust sample collection times were more variable for Family Relocations because some families moved without notifying the Program. Dust lead testing results were delivered to each family in-person or by mail. It is important for the reader to bear in mind that because some families moved more than once, we have more dwellings with relocation dust lead data than families who relocated.

At each sampling visit, trained KKI staff collected three surface-specific composite dust wipe samples from accessible window sills, window troughs, and floors. The evaluation employed a composite sampling methodology due to resource limitations. Each surface-specific composite sample included dust collected in the kitchen, living room or play area and the child's bedroom. Floor samples were collected at the entry to each room using a one-foot square template. Separate composites were collected from uncarpeted and carpeted floors. Alternating halves of window sills and window troughs were sampled from one visit to the next to minimize the impact of sampling on dust lead loadings over time, and the dimensions of the sampled surfaces were measured and recorded.

At the time of this evaluation, Federal, state and local standards existed for post-abatement clearance testing.⁶⁻⁸ There were, however, no Federal, state or local requirements or standards for testing for lead in residential dust in privately owned housing.

Dust wipe samples were digested and analyzed for lead by Azimuth Laboratories using flame-atomic absorption spectroscopy and a modified NIOSH 7082 method. Azimuth was accredited by the American Industrial Hygiene Association (AIHA) under the National Lead Laboratory Accreditation Program (NLLAP) and participated in the New York Department of Health's Environmental Laboratory Approval Program (ELAP). Both NLLAP and ELAP required participation in an external proficiency program. Quality control maintained throughout the evaluation period included standard internal laboratory QC procedures as specified under the AIHA Environmental Lead Laboratory Accreditation Program and analysis of field blanks and double-blind spike samples.

The laboratory had a calculated Method Detection Limit (MDL) of $5 \mu\text{g}/\text{ft}^2$ but did not report any results below $25 \mu\text{g}/\text{ft}^2$. This presented a problem in that many sample results were low and thus reported as $<25 \mu\text{g}/\text{ft}^2$. The laboratory provided the actual instrument response data so that values could be obtained for samples previously reposted as below $<25 \mu\text{g}$. Review of the instrument responses revealed that the analyst had allowed the instrument blank response to extend far into the negative range causing an underestimation of many sample results. This was also corrected when the new standard curves were calculated. After accounting for the negative blank, a linear regression equation, based on the instrument calibration standards for each sample run, was used to recalculate all affected sample results. The same re-calculations were applied to the internal laboratory and field QC samples.

Blood

Venous blood samples were collected in purple top vacutainers by a phlebotomist at the KKI Lead Clinic during routine visits. Specimens were analyzed for lead at the KKI Trace Metals Laboratory (TML) using anodic stripping voltammetry according to the Bannon et al. method.⁹ The TML was CLIA (Clinical Laboratories Improvement Amendments) approved and served as a reference laboratory for both the New York and Wisconsin (CDC) blood lead proficiency programs.

Cost and Demographic Data

Program and relocation costs for all study children were obtained from KKI accounting and social work records. Demographic data were available from KKI social work records on 80 participant families and from structured interviews with all participant families.

Data Analysis

Dust and blood data were log-transformed prior to data analysis. For all dust wipe samples with dust lead loadings (lead loadings) less than the detection limit after correction ($n = 4$ of 833 samples), the value used in the data analysis was the limit of detection divided by the square root of two.¹⁰ Statistical analyses were performed using SAS/STAT® software.¹¹

Dust Lead Paired *t*-tests were used to test for significant change in geometric mean (GM) dust lead loadings over time within a group. Analysis of Variance (ANOVA) and *t*-tests were used to compare geometric mean (GM) levels between groups when groups were independent. In some cases, lack of independence of groups (e.g., a family in more than one group) dictated that nested modeling methods be employed. Fisher's Exact Test was used for tests regarding the proportion of different populations exhibiting given qualities. McNemars test was used to test proportions of different populations exhibiting given qualities for dependent data (e.g., housing unit with dust lead loadings above/below a particular level at baseline compared with housing unit with dust lead loadings above/below a particular level six months or one year later).

All houses with dust data for any given period of interest (e.g., baseline to relocation) were included in the analysis. Because the evaluation was interested in the effect of relocating children from typical high-risk housing, the homes of 11 families living in atypical houses with lead loadings below HUD clearance standards at the time of enrollment were excluded from the analysis of changes in lead loadings.

Lead loading data at baseline and at relocation were compared to the 1995 HUD⁶/EPA¹² post-abatement dust lead clearance standards in effect at the time of the evaluation (i.e., 100 $\mu\text{g}/\text{ft}^2$ for floors, 500 $\mu\text{g}/\text{ft}^2$ for window sills, 800 $\mu\text{g}/\text{ft}^2$ window troughs) and to the current Federal/EPA standards for lead in residential dust (i.e., based on average values within the home for floors: 40 $\mu\text{g}/\text{ft}^2$ and window sills: 250 $\mu\text{g}/\text{ft}^2$ with no well standard specified).¹³

Blood Lead The effect of relocation on blood lead concentration (PbB) was based on an analysis of 41 non-chelated children who had both initial and final PbB measurements. Final PbB was defined as a measurement made 10 to 15 months after the initial PbB. Fifty-one (51) children were excluded from the analysis because a final blood lead measurement was not available. Of the remaining 71 children, 22 children chelated during the evaluation period were excluded from this analysis to eliminate the confounding effects of medical treatment. If more than one child in the family met criteria for this analysis ($N = 4$), the first child in the family placed into the contract Program was selected to avoid confounding due to sibship. Two children residing in houses with dust lead loadings below the 1995 HUD clearance standards at the time of enrollment were excluded from the analysis of blood lead by relocation group because the Program had determined that the children were likely exposed elsewhere. Two children whose houses were abated during the evaluation period were excluded from the analysis of blood lead because the group was too small for separate analysis.

This left 41 participants from three groups (Kennedy relocation, Family relocation, No relocation) who met the criteria for blood lead analysis. ANOVA was performed to assess potential differences between groups in terms of age, geometric mean PbB at enrollment and length of time in study. The *t*-test was used to test the null hypothesis that the change in GM blood lead concentration was the same between two groups. Fishers' exact test was used to test the hypothesis that relocation increases the proportion of children with PbB < 15 $\mu\text{g}/\text{dL}$, the blood lead concentration that triggers case management.¹⁴ For the subset of children with dust data available, *t*-tests were used to evaluate the relationship between GM blood lead concentration and dust lead loadings above or below the current Federal residential dust lead standards.

RESULTS

Demographics

At enrollment, nearly all (96%) families had incomes below the Federal poverty level in Baltimore City¹⁵ and received some form of public assistance. Most (81%) families lived in rental properties at baseline; 12% were owner-occupied, and 7% lived in family-owned houses. The median monthly household income for families was \$900. Nearly one quarter (22%) of the families reported involvement with three or more publicly funded programs. Nearly two thirds (63%) of families reported outstanding utility bills. Most (94%) participants were African American. The median monthly rent based on family report was \$300. At the time, median monthly rent for a comparable sized, lead-safe relocation home was \$485 (personal communication, Coalition to End Childhood Lead Poisoning, Baltimore, Maryland, 1998). The typical household had five people—two children under the age of 6 years, one child 6 to 18 years of age, an unmarried single female head of household and another adult over the age of 18. The median age of study children at enrollment was 36 months (range 9–90 months). Sixty percent of study children were male.

Relocation

Of the 107 study families, 84 (79%) relocated at least once during the period of follow-up. Forty-three families (51% of all families that relocated at least once) relocated at least twice, and 11 families relocated at least three times. Most families relocated with direct assistance from the Program (Kennedy Relocation, $n = 51$ families). Other families relocated themselves (Family Relocation, $n = 33$ families) with only indirect Program assistance. Twenty-three families did not relocate (No Relocation). Relocation information was unavailable for one family. In two thirds of cases, program social workers accurately predicted that a family would move, but only half of their predictions that a family would not relocate were correct. Families who lived in rental property at enrollment were more likely to relocate than families in owner occupied or family occupied properties ($p = 0.01$). Seventy-five percent of families in rental properties at enrollment relocated compared to 40% of families living in owner-occupied or family-occupied dwellings.

The interval between enrollment and the first relocation was approximately five months (mean = 179 days, median = 154 days) for both Kennedy and Family Relocation groups. No differences were found in relocation time between children who received chelation therapy and those who did not. On average, the relocation house was 2.3 mi ($n = 74$, range = 0.002–12.6 mi) from the enrollment house for both Kennedy and Family Relocations.

Thirty-nine percent (20 of 51) of the Kennedy Relocation families remained at their relocation address for at least 6 months and 25% (13 of 51 families) stayed for at least 12 months. Two families completed two Kennedy Relocations. Nine families who were relocated by the Kennedy Program later relocated a second time without the direct Program assistance. Comparable retention information is not available for Family Relocations. Eight (7%) families were lost to follow up before the Program was able to document their location at six months.

Dust Lead Findings by Relocation Group

At enrollment, 14% of dwellings with baseline data had lead loadings below the 1995 HUD clearance standards in effect at the time. At the time of relocation, 65%

of KKI Relocation dwellings had lead loadings below the 1995 HUD clearance standards in effect at the time compared to 33% of Family Relocation dwellings and to 26% of dwellings remaining in the No Relocation category since enrollment (Table 1). Less than half (47%) of the KKI Relocation houses would meet the current Federal (US EPA 2001) standards.¹³

Change in Dust Lead Loadings After Enrollment

Sixty-four families had dust sampled at time of enrollment and six months later. Fifty-nine families had dust sampled at time of enrollment and 12 months later. The proportion of houses with dust lead loadings below the 1995 HUD clearance standards⁶ and Federal (U.S. EPA 2001)¹³ residential dust lead standards increased significantly for KKI Relocation families at six and 12 months compared to baseline. The KKI Relocation group was the only group where most houses had dust levels below both EPA and HUD standards over time. Although there were some improvements over time in dust lead loading for both the Family Relocation and the No Relocation groups, the changes over time were not statistically

TABLE 1. Percentage of dwellings with dust lead loadings below federal standards at baseline and at time of relocation

Dwelling group and time	No. dwellings	Dwellings meeting HUD 1995 dust clearance standards*		Dwellings meeting EPA 2001 dust standards†	
		<i>n</i>	Percent	<i>n</i>	Percent
All dwellings at enrollment‡	99	14	14	11	11
A. Dwellings of families who did not relocate	23	6	26	4	17
B. Dwellings of families who did relocate	65	7	11	7	11
C. Dwellings of families with enrollment dust only§	11	1	9	0	0
All Family Relocation dwellings—at the time of relocation	45	15	33	10	22
All Kennedy Relocation dwellings—at the time of relocation¶	51	33	65	24	47

*Defined as dwellings where all floor, window sills and window trough samples met the 1995 HUD lead dust clearance standards in effect at the time of the evaluation: floors: <100 µg/ft², window sills: <500 µg/ft², window troughs: <800 µg/ft².

†Defined as dwellings where all floors, sills, and trough samples all met EPA residential dust lead standards in effect in 2001: floors: <40 µg/ft², window sills: <250 µg/ft², window troughs <400 µg/ft² (clearance standard only).

‡Baseline dust was available for the dwellings of 99 enrolled families. Baseline dust was not available for the homes of 13 families because the family relocated quickly before study personnel could collect baseline dust samples.

§Includes one dwelling, later abated, and five dwellings of families subsequently de-enrolled from this evaluation.

||Includes all Family Relocation addresses with dust data, including addresses of Kennedy relocation families that relocated themselves either before or after their Kennedy relocation. Some families moved multiple times.

¶Includes all KKI relocation addresses; some families moved multiple times.

significant. When combining the Kennedy and Family Relocation groups, statistically significant decreases in dust lead loadings were also found over time (Table 2). The geometric mean window sill lead loadings at baseline were significantly higher for owner-occupied and family occupied properties compared to rental properties (GM = 2,981 $\mu\text{g}/\text{ft}^2$ vs. 502 $\mu\text{g}/\text{ft}^2$, $p < 0.01$), but there was no difference in floor or trough loadings between the two groups ($p = 0.94$ and $p = 0.17$, respectively).

**Change in Dust Lead Loadings Over Time
by Relocation Status**

Table 3 displays the GM dust lead loadings over time by group and surface type. At enrollment, there were no significant differences in GM dust lead loadings of homes for the three relocation groups (i.e., Kennedy Relocation, Family Relocation and No Relocation) on floors, window sills or window troughs (Nested model; $p = 0.35$, $p = 0.08$ and $p = 0.30$, respectively). Families in the Kennedy Relocation Group experienced a statistically significant decrease in dust lead exposure (e.g., dust lead loading for floors, window sills and window troughs) compared to dust lead exposure at homes where the families lived at time of enrollment. Although families in the Family Relocation Group also experienced a decrease in GM dust lead loadings after relocation, statistically significant change from enrollment homes was

TABLE 2. Percentage of dwellings with dust lead levels below federal standards at baseline and at 6 and 12 months after enrollment, by group

Group	No. dwellings	% dwellings below HUD 1995 clearance standards at enrollment	% dwellings below HUD 1995 clearance standards at 6 months [†]	% dwellings below EPA 2001 standards at enrollment	% dwellings below EPA 2001 standards at 6 months [†]
6 months					
Kennedy relocation	19	0	79 [‡]	0	58 [‡]
Family relocation	15	13	27*	13	13
All relocations [§]	34	6	56**	6	38**
No relocation	30	20	20	13	17
Total	64	12	39**	9	28**
12 months					
Kennedy relocation	22	14	86**	14	55**
Family relocation	21	10	33	10	33
All relocation [§]	43	12	60**	12	44**
No relocation	16	12	31	6	19
Total	59	12	53**	10	37

* = significant change from baseline, t -test $0.01 < p \text{ value} < 0.05$.

** = highly significant change from baseline, t -test $p \text{ value} < 0.01$.

[†]The p value from McNemar's test that the proportion below the standard is the same at the two times.

[‡]The percentage change cannot be determined because zero percent of houses were below standards at the time of enrollment.

[§]All relocation equals Kennedy and Family Relocation groups combined.

TABLE 3. Geometric mean (GM) dust lead loadings ($\mu\text{g}/\text{ft}^2$) over time by group and surface

Group	Surface type	Before relocation		At time of relocation		6 months [†]		12 months [‡]	
		GM	(n)	GM	(n)	GM	(n)	GM	(n)
Kennedy Relocation	Floor	55	(39)	10	(44)**	13	(28)**	11	(13)*
	Window sill	1,300	(38)	58	(44)**	32	(28)**	18	(13)**
	Window trough	25,000	(36)	400	(41)**	220	(27)**	240	(13)**
Family Relocation	Floor	48	(32)	24	(31)	15	(32)*	20	(11)*
	Window sill	620	(31)	220	(32)*	74	(22)*	280	(11)
	Window trough	21,000	(30)	4,700	(31)	1,200	(26)**	1,200	(10)*
No Relocation	Floor	31	(26)	n/a		41	(30)	28	(19)
	Window sill	400	(27)			290	(30)	160	(20)
	Window trough	8,400	(25)			5,800	(28) ^{bl}	1,200	(19)*

* = significant change from the before relocation baseline, t -test $0.01 < p \text{ value} < 0.05$.

** = highly significant change from the before relocation baseline, t -test $p \text{ value} < 0.01$.

^{bl} = borderline significance, t -test $p \text{ value} = 0.07$.

[†]Refers to 6 months post relocation for Kennedy and Family relocation groups; 6 months post baseline for No-relocation group.

[‡]Refers to 12 months post relocation for Kennedy and Family relocation groups; 12 months post baseline for No-relocation group.

Values in the table are reported to two significant digits.

observed only for window sills. The GM dust lead loadings were significantly different and lower for the combined group of Family and Kennedy Relocation homes at the time of relocation compared to homes where families lived at baseline for floors, window sills and window troughs (Nested model; $p = 0.03$, $p = 0.01$, $p = <0.01$).

Six months after relocation, the dust lead loadings on floors, window sills and window troughs for both Kennedy and Family Relocations were significantly different and lower than dust lead loadings of homes where families lived at enrollment. However, the window trough and window sill dust lead loadings of the two groups of homes at six months were significantly different (both $p < 0.05$) with loadings for Family Relocations higher than loadings for Kennedy Relocations, when controlling for relocation dust levels. We found no significant differences in dust lead loadings for homes in either group between relocation and six months after relocation. Homes in the No Relocation group showed no statistically significant changes in dust lead loadings over the six month period, although a large downward trend was noted in window trough dust lead loadings.

Twelve months after relocation, dust lead loadings on floors, window sills and window troughs for Kennedy Relocation homes and on floors and troughs for Family Relocation homes remained significantly different and lower than the corresponding levels at baseline. No differences, however, were found between the two groups when controlling for relocation dust lead levels. No significant

differences were found for dust lead loadings in either group of homes from time of relocation to 12 months post-relocation or from 6 months post-relocation to 12 months post-relocation. For the No Relocation group, only the window trough dust lead loadings were significantly different and lower at 12 months compared to baseline ($p < 0.05$).

Changes in Blood Lead Concentration Over Time by Group

No statistically significant differences were found between groups (i.e., Kennedy Relocation, Family Relocation, and No Relocation) in terms of initial GM blood lead concentration (ANOVA $p = 0.68$), age at initial blood lead test (ANOVA $p = 0.57$), and the time interval between initial and final blood testing (ANOVA $p = 0.41$).

Each relocation group had a statistically significant reduction (paired t -tests $p < 0.01$) in GM blood lead concentration (PbB) between the initial and final measurement 10 to 15 months later (Table 4). The changes in GM PbBs between-groups were significantly different only for the Kennedy Relocation and No Relocation groups ($p = 0.01$). Although the Family Relocation group had a greater reduction in PbB than the No Relocation groups, the difference was not statistically significant (t -test $p = 0.10$). One third of all relocated children had a final PbB < 15 $\mu\text{g/dL}$ compared to 9% of children who did not relocate, but this difference was not statistically significant (p value = 0.12 Fishers exact test). A linear model was run to predict log final PbB based on log initial PbB, age at initial PbB (≤ 27 months or > 27 months), and the interaction between these two variables. Neither interaction nor age was a significant predictor of final PbB ($p = 0.47$, $p = 0.14$, respectively). We ran additional analyses to determine if the 41 children for whom we had final blood lead levels were different from 68 other children in the study for whom we did not have final blood lead levels. We found no statistically significant differences in age ($p = 0.9512$) or gender ($p = 0.8433$) between the two groups. However, the differences between groups by race were marginally significant ($p = 0.0814$), and none of the white children ($N = 6$) were in the group with follow-up blood data.

Many of the families in this program had difficulty relocating. One year after enrollment, 18% (19/108) of study families were still residing in unsafe homes where they had lived at the time of enrollment. Additionally, 48% of families who did eventually relocate spent an average of four months in their enrollment home. We used a Repeated Measures Model to evaluate the effect of the KKI Program on PbB prior to relocation. The model predicted that the KKI Program alone accounted for the following decreases in GM PbB over a 1-year period:

	Initial	3 mos	6 mos	12 mos
PbB ($\mu\text{g/dL}$)	24.2	22.9	21.7	19.4
Change ($\mu\text{g/dL}$)		-1.3	-2.5	-4.8

This is very similar to the average 4.2 $\mu\text{g/dL}$ decline in PbB observed in Milwaukee in association with a program of in-home educational visits to families with PbBs in the 20–24 $\mu\text{g/dL}$ range.¹⁶

We evaluated change in blood lead levels for a subset of 29 non-chelated children with complete sets of blood and dust lead data. Children living in homes

TABLE 4. Reductions in geometric mean blood lead concentration ($\mu\text{g/dl}$) one year after enrollment by group*

Group	N	Initial GM blood lead level (95% CI)	Final GM blood lead level (95% CI)	Absolute reduction in GM	Percent reduction in GM
Kennedy Relocation	18	26.9 (24.3, 29.7)	17.0 (15.0, 19.4)	9.9	37*
Family Relocation	12	25.4 (22.5, 28.7)	16.6 (13.6, 20.2)	8.8	35*
No Relocation	11	24.7 (21.8, 28.0)	19.7 (17.0, 23.0)	5.0	20*

*Each group had a statistically significant reduction in GM blood lead concentration (p value <0.0001).

with dust lead loadings below the current Federal residential dust lead standards had a larger reduction in GM PbB (11.6 $\mu\text{g/dL}$, 41.3%) compared to children whose homes did not meet these standards (4.8 $\mu\text{g/dL}$, 19.8%). The difference in the changes between the two groups was statistically significant (<0.01), as was the change in GM PbB for each group (<0.01).

No child who was relocated had an increase in PbB ≥ 5 $\mu\text{g/dL}$ after relocation except for one child who subsequently moved back to the home where the family had lived at the time of enrollment. On the other hand, 13% of children had an increase in PbB ≥ 5 $\mu\text{g/dL}$ during follow-up while living in the home where they were identified with an elevated blood lead concentration, typically within 10 weeks of their enrollment visit.

Costs

Non-clinical program costs, which included an in-home cleaning demonstration for each family and work by program staff (housing assessors, social workers, Program coordinator), were approximately \$1,000 per child per year across all groups. Program relocation costs, which included security deposits, application fees, moving expenses, rent subsidy, utility bill payments, transportation, professional cleaning at relocation homes and emergency cleaning at baseline homes, ranged from \$0 to \$3,094 for an individual child (mean = \$743, median = \$470), for a total program cost per child of approximately \$1,500. Relocation costs of \$0 occurred when a family did not relocate or moved without requesting money from the flexible pool of funding. The Program incurred relocation costs for many families who ultimately relocated themselves (Family Relocation Group) and for some families who never relocated during the course of the evaluation. Relocation costs were higher for chelated children than non-chelated children. Relocation costs incurred by the Program were higher for the Kennedy Relocation group compared to the Family Relocation group. The total program cost of approximately \$1,500 per child compares favorably with the average cost of \$7,600 for residential lead paint abatement work conducted by the HUD program operating in Baltimore at the time (Personal Communication, Sherry Dixon, NCHH).

The costs of emergency and relocation house cleaning conducted by professionals were included in the over-all relocation costs. Twenty children (17%) received paid cleaning services costing \$116 to \$2,120 (mean = \$428; median = \$381). The Program typically provided professional cleaning when a chelated child was to be discharged from the hospital before the family could be relocated or when a family was unwilling to relocate.

DISCUSSION

This program evaluation was difficult and the results were at times confusing due to frequent and unpredictable changes in family circumstances. However, this evaluation shows that relocation is achievable and affordable with a combination of flexible clinical dollars and social work and housing-related assistance. Relocation to safer housing with lower dust lead exposures contributes to effective management of lead poisoned children and has potential for contributing to primary prevention among other children in the household. The fact that 13% of families experienced a significant increase in PbB ($>5 \mu\text{g/dL}$) within ten weeks of enrollment while living in the home where they were identified underscores the importance of taking immediate action to decrease exposure to lead hazards in homes of lead poisoned children. The dust and blood lead findings validate CDC's recent case management recommendations suggesting that relocation to safer housing is an alternative means to reduce children's lead exposure.¹⁴ Moreover, contrary to anecdotal beliefs of many health care providers, families were willing to move to safer housing outside their enrollment neighborhoods, suggesting that for our population neighborhood, ties may be less important than other factors.

Renters were very open to the idea of moving, particularly if help was offered. Owner occupants and families living in homes owned by a relative were much less likely to move, suggesting that other strategies should be considered, including emergency cleaning and lead hazard control. No incentives were provided for this evaluation; families participated in the evaluation and the program because they believed it would be beneficial to their children. If safe and affordable relocation housing is available and extensive lead hazard control work is needed, programs managing lead poisoned children should consider assisting families with permanent relocation. In some cases, permanent relocation is necessary due to dilapidated and distressed housing conditions; the scope, cost and timing of abatement work; a lack of resources; property owner compliance; local enforcement capacity; and eviction. Relocating the family, however, does not negate the responsibility of local health authorities and the property owner to address the lead hazards in the child's original house in order to protect future occupants.

Relocation was possible due to the combined efforts of a multi-disciplinary team with access to flexible program funds for reducing multiple impediments to relocation. Social workers conducted psychosocial assessments to tailor relocation assistance and support to individual families' needs and circumstances. The housing resources coordinator developed key relationships with landlords and maintained a list of safer rental housing. Field staff contributed to the Program's success by providing in-home, house-specific education to raise family awareness about protecting themselves from residential lead hazards. Others replicating this program should adopt a multi-disciplinary approach.

Many factors made relocation difficult, including higher rents associated with lead-safe relocation housing, outstanding utility bills, owner occupancy and the extent of physical and organizational effort and time required by families to relocate. The most important obstacle to relocation was higher rents associated with safer relocation housing. At enrollment, family rents accounted for an average of 32% of their extremely low monthly family incomes. Rent for a safer relocation property was typically more than half the average monthly income of participating families, making it financially difficult for all and impossible for some families to relocate.

A program survey of 90 Baltimore City property owners done as part of this evaluation found that 75% were willing to rent to families from the KKI program despite the fact that only 49% of owners reported that that KKI families were “good” at making rental payments. Landlords reported that they liked having families connected to a social service agency and would be willing to take families who had a history of non-payment of rent if they were supported by such a program. Landlords were often reluctant to accept families with outstanding utility bills. The local utility company would not initiate service at a relocation address until a formal payment plan was well underway, yet families were often unable to make the significant cash payment required to begin a payment plan. Although the Program provided financial assistance to help families establish payment plans, outstanding bills for some families were beyond the financial means of the Program. In some cases, KKI social workers were able to assist families in relocating to properties that included heat and hot water as part of the rent.

Relocation costs were higher for children who received chelation therapy compared to non-chelated children due to the urgent need to discharge them to a lead safe environment following chelation therapy that typically lasted 30 days. Additional emphasis was placed on emergency cleanings in homes of families with chelated children who were unable or unwilling to relocate immediately.

Relocation to housing visually inspected by trained Program staff resulted in a statistically significant reduction in exposure to lead dust that persisted for 12 months. Visual inspection, however, was not sufficient to identify houses with lead loadings consistently below current residential dust lead standards. More than half (53%) of the relocation houses that had passed visual inspection had floor or window sill dust lead loadings above the current Federal residential dust lead standards. Future programs need to assess lead dust levels in potential relocation houses to ensure that they meet current standards. Houses not meeting those standards would need intervention and additional testing prior to occupancy.

This evaluation assessed changes in children’s blood lead concentrations as another outcome of interest, recognizing that the nonrandomized nature of the evaluation design would limit our ability to interpret the effect of relocation on children’s blood lead concentrations. All groups experienced statistically significant reductions in blood lead concentrations. Although statistically greater reductions in PbB were observed only for children in the KKI Relocation group compared to the No Relocation group, the percent reductions in PbB were similar for both KKI and Family relocation groups. The similarity of reductions in PbB between the KKI and Family relocation groups, despite documented differences in residential dust lead loadings, may be due to small sample sizes and the fact that most relocation housing was located in older city neighborhoods where lead-based paint hazards are common. Importantly, the blood lead concentrations of nearly all of the children who relocated did not increase.

We did not have one-year blood leads for all children participating in this evaluation. However, the data we do have suggests a clear relationship between environmental exposure and blood lead as has been identified in other studies. Despite the study limitations, this is important information because it confirms the importance of decreasing environmental exposures in the homes of lead poisoned children.

Although the sample size was small and the results were not statistically significant, relocation was associated with an increase in the percentage of children

with PbBs below 15 µg/dL, another outcome of interest for case managers. This difference may also be due in part to the aging of the children (median age at enrollment = 36 months) or to selection bias. Pre-existing body burdens of lead in these children might have moderated the effects of relocation on blood lead concentrations over time.¹⁷

Two other factors limited the potential effectiveness of the relocation approach. The first was the average 5-month period between enrollment and relocation. Seventeen percent of families moved within two months; a few families took more than a year. The variable time for relocation was due to a number of family and landlord factors, including time needed for family decisions, resolution of outstanding utility bills, identifying and visiting relocation housing, and scheduling visits to families' homes by prospective landlords to assess the families' housekeeping. Other factors included school and childcare considerations, the level of family organization and the sheer organization and physical effort required to prepare for and complete a move. In this program, social workers' predictions that a family would not move were incorrect 50% of the time. Therefore, programs should encourage relocation even with renter families who seem less likely to move.

It is important to note that the long-term control of residential lead hazards for case management is time and resource intensive. Both abatement and relocation take time to implement: an average of five months to relocate families in this Program compared to an average of eight months to complete lead hazard control work in 14 municipal and state lead hazard control programs funded by U.S. HUD (personal communication, Jonathan Wilson, National Center for Healthy Housing). Relocation, however, can be less costly as well as more timely than abatement, which in many cases also requires temporary relocation to protect families. However, addressing environmental hazards quickly as an emergency measure is critical to protect children who remain at risk of further blood lead increases after being identified as lead poisoned. This underscores the need for timely interim measures to reduce exposure such as the professional cleaning offered by this program.

The second factor limiting the effectiveness of relocation and complicating the evaluation was the extent and the frequency of subsequent family moves. The authors recognize that there is a fair amount of instability within this population. In this program, 27% of families living in owner-occupied or family owned properties moved two or more times during the evaluation period compared to 54% of families living in rental housing. Many of the families in our study had moved prior to being enrolled in the study and kept on moving even after they had moved into a house that met program relocation criteria. Turn-over is common even in fully abated rental properties in Baltimore: Approximately 15% of properties enrolled in the National HUD Evaluation in Baltimore had two tenants during the first year after abatement, and 3% had 3–4 tenants.¹ Further research is needed to understand why this occurs, how to stabilize families and how to minimize subsequent moves so that families remain in safer relocation housing particularly during their children's pre-school years when risk of lead poisoning is the greatest. We believe that the inclusion of utility payments as part of rent and an increase in the availability of rental subsidy programs like Section 8 would be helpful. From a tenant perspective, having a Section 8 voucher is very advantageous because it enables them to stay in decent housing. Maryland's *Lead Risk Reduction in Housing* law, which went into effect during the evaluation period, provides for such a rent subsidy to families with lead poisoned children paid for by the property owner who is also responsible for relocation expenses.¹⁸

Relocation is relatively inexpensive compared to HUD abatements in Baltimore. Average costs for HUD abatements in Baltimore City during the period 1994 to 1996 was \$7,600. On average, it took the Baltimore HUD Abatement program 39 days to complete an abatement in an occupied property. Furthermore, 18% of the occupied Baltimore rental properties that were abated by the Baltimore Abatement program had a change of occupancy within the first two years after enrollment.

Eighty-nine percent of homes of children at the time of enrollment in this Program had dust lead levels above current Federal residential dust lead standards, demonstrating the high-risk nature of home environments where children are being poisoned. Because of the burden that lead poisoning places on society and individual families, more intensive efforts should be made to improve safety of the housing stock in high-risk neighborhoods before children are poisoned. Primary prevention approaches that address lead hazards in high risk housing stock, incorporate a housing standard of care for older housing (like Maryland's EA-6-8) and that employ dust standards should reduce both the burden of lead poisoning and the need for case management.

All families in the Program were provided with a comprehensive educational intervention, including an in-home cleaning demonstration, cleaning supplies, specific recommendation for protecting their child based on the visual inspection of their home, dust test results, and assistance with interim hazard control (e.g., covering areas of peeling, chipping paint with duct tape and plastic). Consistent with other studies,^{16,19,20} our findings suggest a minimal effect of education. In the homes of families who did not relocate, significant reductions in dust lead loadings were only found for troughs and only at 12 months after initial education. We did not see significant reductions in floor or sill dust lead loadings. All increases in PbB levels ≥ 5 $\mu\text{g}/\text{dL}$ occurred within 10 weeks of enrollment in homes of 13% of all Program families who did not relocate or who had not yet relocated but had received comprehensive education.

These dust and blood lead findings considered together with the time required for relocation support the need to implement dust testing and emergency hazard reduction measures in all homes of lead poisoned children. This short-term intervention, recommended by CDC's 2002 case management guidelines,¹⁴ would rapidly reduce lead exposure, particularly if the home contains hazardous levels of lead dust and paint chips, and help protect children until a longer-term more permanent intervention could be put into place.

Dust testing should be done as part of the initial home assessment to evaluate risk and to educate the family about areas in the home that are particularly hazardous. Additional dust testing should be done following interventions and to monitor change and evaluate the effectiveness of case management. Programs should also examine administrative and family constraints to determine how best to improve timely delivery of case management services and to reduce relocation times. The current low cost of laboratory analysis for individual dust wipe samples will enable programs to perform testing of individual floors, window sills and window troughs in more rooms, thus improving the assessment of risk throughout the home and improving the ability to target emergency hazard reduction measures.

Generalizability The success of any program designed to assist families with relocation is dependent, in part, on the availability of safe and affordable relocation

housing. Ideally, in a city like Baltimore, a critical stock of lead-safe housing would be available so that families who move frequently would be more likely to move into another safe unit. This Program was conducted in a city with a fluid rental housing market, an active lead abatement program, and a state with clear property standards for pre-1950 rental housing, all which helped to make relocation possible with a program focused on identifying safe and affordable relocation houses for a relatively small number of families. Through relationships with property owners, the Program was able to increase over time the pool of safer housing available to families of lead poisoned children. Larger scale programs or communities with tighter, more expensive rental housing markets and without the political will to require lead abatement of hazardous properties could find it more difficult to identify sufficient quantities of safe and affordable relocation housing. Lastly, Program costs in Baltimore, including the average per child cost for relocation assistance (<\$1,500), may not be generalizable to other communities due to differences in costs for staff, services and other factors. The emergency hazard reduction measures and additional dust testing discussed above may increase both the costs and benefits of future programs.

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