Immigration and Risk of Childhood Lead Poisoning: Findings From a Case–Control Study of New York City Children

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Objectives. We investigated whether foreign birthplace and residence were associated with an increased risk of childhood lead poisoning.

Methods. We conducted a matched case–control study among New York City children (mean age = 3 years) tested for lead poisoning in 2002 (n = 203 pairs). Children were matched on age, date of test, and residential area. Blood lead and housing data were supplemented by a telephone survey administered to parents or guardians. Conditional logistic regression analysis was used to examine the relationship of lead poisoning status to foreign birthplace and time elapsed since most recent foreign residence after adjustment for housing and behavioral risk factors.

Results. Both foreign birthplace and time since most recent foreign residence had strong adjusted associations with lead poisoning status, with children who had lived in a foreign country less than 6 months before their blood test showing a particularly elevated risk of lead poisoning relative to US-born children with no foreign residential history before their blood test (odds ratio [OR] = 10.9; 95% confidence interval [CI] = 3.3, 36.5).

Conclusions. Our findings demonstrate an increased risk of lead poisoning among immigrant children. (*Am J Public Health.* 2008;98:92–97. doi:10.2105/AJPH.2006.093229)

Despite a dramatic decline in childhood lead poisoning in the United States, an estimated 1.6% of US children aged 1 to 5 years (approximately 310 000 children) have elevated blood lead levels of at least 10 µg/dL. Furthermore, the growing scientific evidence on cognitive impairments associated with blood lead levels below 10 µg/dL suggest that even a greater number of children are at risk of being adversely affected by low-level exposure to lead.[2–4]

The most common high-dose source of lead exposure among US children is interior lead-based paint,[5–8] but children who spend time outside the United States may be exposed to additional sources. The literature on lead poisoning among immigrant children living in the United States is scant. Surveillance and case studies have revealed a higher prevalence or incidence of elevated blood lead levels among refugee and internationally adopted children living in the United States than among the general US population of children.[9–12] However, these reports have lacked a comparison group and presented results not adjusted for confounding factors.

To our knowledge, a recent national study involving Mexican American children is the only investigation in which individual- and family-level characteristics (e.g., age, family income, language spoken at home) and source of drinking water were controlled for in any examination of the association between foreign birthplace and lead poisoning. The results of that study revealed higher blood lead levels among foreign-born children than among US-born children of Mexican descent.[13]

In this study, we examined the associations of childhood lead poisoning with birth and residence in a foreign country among a multiethnic urban sample while accounting for child and family demographic characteristics, child behaviors, and current residential building characteristics. We hypothesized that lead poisoning would be positively associated with birth and residence in a foreign country after control for known risk factors.

METHODS

Design

We used a matched case–control (1:1) design, which allowed for a relatively low-cost study, a small sample size, and efficient control for a complex web of demographic and environmental factors. Participants were recruited and data were collected during 2002 and 2003.

Children were matched on age (mean age difference: 3 months; range: 0–9 months), date of lead poisoning test (mean test date difference = 17 days; range = 2–91 days), and residential area (defined via aggregated contiguous zip codes as established by the United Hospital Fund[14]). We included these variables because the prevalence of children's mouthing behaviors (placing objects and hands in mouth) and their likelihood of undergoing blood lead testing decrease with age,[6,15] both blood lead testing and blood lead levels exhibit seasonal trends,[16,17] and building characteristics, blood lead levels, and likelihood of blood lead testing are associated with area of residence.[14,18,19]

Data Sources

Children eligible to participate were younger than 18 years, resided in New York City, had been tested for lead poisoning between May and December 2002, and had blood lead test results reported to the blood lead registry of the New York City Department of Health and Mental Hygiene's Lead Poisoning Prevention Program (LPPP; in New York State, laboratories are required to report all blood lead tests to the state health department). Case children were defined as those having a first-time blood lead level of 20 µg/dL or greater from a venous sample or 2 tests with blood lead levels between 15 and 19 µg/dL taken at least 3 months apart, with the second test involving a venous sample (LPPP's definition of lead poisoning cases requiring environmental interventions during the study period). Control children had blood lead levels of 5 µg/dL or below from a venous or capillary sample and no previous elevated blood lead level.

All blood samples were analyzed by laboratories certified by the New York State Department of Health. We obtained information on blood test date, lead level, child's date of birth, and parent or guardian's name and address from the blood lead registry. We gathered information on building age and size from databases maintained by the city of New York. A 30-minute structured telephone questionnaire, administered to the parents or guardians of both case children and controls, was used to collect data on family income, potential sources of lead paint exposure in the home, and child's gender, race/ethnicity, mouthing behaviors, country of birth, and foreign residential history. We pilot tested the questionnaire via a focus group and pretest interviews and translated it into Spanish.

Data Collection

A multilingual introductory letter was mailed to the parents or guardians of 1058 eligible children. At least 4 attempts were subsequently made to contact the parents or guardians by telephone. We were more successful in contacting parents or guardians of the 308 potential case children (78%) than the 750 potential control children (49%), primarily because, for 2 reasons, we had better contact information for the former. First, case children's blood test results were reported to LPPP by both laboratories and health care providers, whereas control children's results were reported by laboratories only. Second, LPPP visited the homes of case children as part of care coordination and environmental assessment activities.

More families in the control group than in the case group refused participation in the study (22% of the control families vs 12% of the case families contacted). We were unable to assess differences in participation according to foreign birthplace or residence because this information was not available for any of the control families, nor was it available for some of the case families that were not interviewed.

We interviewed 211 parents or guardians of case children and 288 parents or guardians of controls. Six case children were excluded because their matched controls were not successfully enrolled into the study. In addition, 2 case children were excluded as a result of missing or incorrect birth dates. When there were multiple controls, the first successfully interviewed control was selected. The final sample included 203 case–control pairs.

As a means of maximizing participation among immigrant families that spoke languages other than English, trained bilingual English and Spanish speakers conducted the interviews, and professional interpreters made the initial contacts with the households and administered the questionnaire if needed. The questionnaire was administered in Spanish to 33% (135) of participants and in Haitian Creole to a single participant in the final sample. The distribution of interview language was similar for case and control children.

Initially, interviewers asked to speak with the mother or father of the child; if the mother and father were not available, they asked, in descending order, for the child's guardian or any available adult relative. For the most part (89% of case children and 95% of control children), parents rather than other adults were interviewed.

Measures

Children were categorized as US born or foreign born (children born in Puerto Rico were classified as foreign born). Parents or guardians were asked whether their child had lived outside of the United States for at least 2 months; if they answered yes, they were asked to provide dates of residence. To capture the timing of potential lead exposures in foreign countries, we calculated the length of time between the most recent date of foreign residence and the time of blood lead testing among children who had lived outside of the United States.

Because only a small percentage of children had lived in a foreign country (17%) and exploratory analyses suggested that the risk of lead poisoning dropped sharply approximately 6 months after most recent foreign residence, we used a simple classification scheme in which 6 months was designated as the cutoff point. That is, children were grouped in the following categories for the final analysis: (1) lived in a foreign country less than 6 months before their blood test, (2) lived in a foreign country 6 or more months before their blood test, and (3) did not live in a foreign country before their blood test.

A major pathway for lead exposure among urban children is ingestion of deteriorated leaded paint and household dust that have settled on their hands or on objects.[5–8] Lead-based paint hazards are more likely to be present in buildings constructed before 1950, when use of lead paint was more widespread than in later years. We categorized time of building construction as before 1950 versus 1950 or after.

Parents were asked about the presence of peeling or chipping paint in their home and were asked whether their children put their fingers in their mouths or ate any nonfood items (e.g., toys, crayons). Both of these measures were dichotomized for the purposes of our analysis. Because New York City laws aimed at preventing children's exposure to lead paint hazards in housing apply to buildings with 3 or more dwelling units, larger buildings may contain fewer lead paint hazards. Thus, we expected lead poisoning to be inversely associated with building size, categorized according to number of dwelling units (fewer than 3 vs 3 or more). Finally, we asked about use of imported products known to contain lead (e.g., traditional Mexican folk remedies such as *azarcon* and *greta*).

Data Analysis

We used odds ratios (ORs) derived from conditional logistic regression analyses to examine bivariate associations of lead poisoning status with foreign birthplace, time elapsed since most recent foreign residence, and other potential risk factors. In addition, we examined associations between lead poisoning status and foreign birthplace and time since most recent foreign residence in separate conditional logistic regression models that adjusted for potential confounders exhibiting statistically significant bivariate associations with lead poisoning status.

RESULTS

The mean age of the sample was 3 years (range: 0–17 years), and 75% of the children were younger than 5 years. As expected, foreign birthplace and time elapsed since most recent foreign residence were strongly correlated (Spearman rank correlation = 0.80, $P < .001$); thus, we were not able to examine their independent effects in the same model. Table 1 presents the characteristics of case and control children and the bivariate associations between each independent variable and lead poisoning status.

Twenty percent of case children were born outside of the United States, as compared with 4% of control children (Table 1). Similarly, case children were more likely than were control children (27% vs 8%) to have lived outside of the United States for at least 2 months. In addition to 50 foreign-born children, 22 US-born children (15 case children, 7 control children) had lived in a foreign country at some time before their blood test. Finally, 3 children (1 case child and 2 control children) had lived abroad for 2 months or longer more than once.

There were differences in foreign countries of birth and residence between the case and control groups. Among case children, the main foreign countries of birth and residence were Haiti, Pakistan, Mexico, and the Dominican Republic; among control children, the primary countries were Puerto Rico and the Dominican Republic. There were no differences in use of imported products between the case group and the control group (data not shown).

Both foreign birthplace and time since most recent foreign residence were strongly associated with lead poisoning status; children who had lived in a foreign country less than 6 months before their blood test were at particularly elevated risk of lead poisoning relative to US-born children with no foreign residential history before their blood test (OR=9.0; 95% confidence interval [CI]=3.2, 25.7; Table 1). Building characteristics and child behavioral characteristics were associated with lead poisoning status in the expected directions. Case and control children were similar in terms of family income. Percentages of children of African American and Hispanic descent were roughly similar in the 2 groups, although case children were disproportionately Asian.

Table 2 summarizes the results of a series of conditional logistic regression models testing our hypothesis that birth and residence in a foreign country would be associated with an increased risk of lead poisoning. After adjustment for housing and child behavioral risk factors, foreign-born children were 5 times more likely than were US-born children to be lead poisoned (OR=5.4; 95% CI=2.2, 13.5; Table 2, model 1).

A history of foreign residence was also strongly associated with lead poisoning status in adjusted models. Children living abroad for less than 6 months and for 6 or more months before their blood test, respectively, were 11 and 3 times more likely to to be lead poisoned than were US-born children who had not lived in a foreign country (Table 2, model 2). Reclassification of 3 control children born in Puerto Rico as US born strengthened the associations between

TABLE 1—Sociodemographic and Risk Characteristics of Participants, by Case–Control Status: New York City, 2002–2003

	Case Group, No. (%)	Control Group, No. (%)	Unadjusted OR (95% CI)
Place of birth			
Foreign country[a]	41 (20.1)	9 (4.4)	5.57 (2.49, 12.45)
United States	162 (79.8)	194 (95.6)	Reference
Time since most recent foreign residence[b]			
< 6 months	33 (16.4)	4 (2.0)	9.00 (3.16, 25.65)
≥ 6 months	21 (10.4)	12 (5.9)	2.26 (1.04, 4.90)
Did not live in a foreign country	147 (73.1)	187 (92.1)	Reference
Race/ethnicity			
Hispanic	82 (40.4)	100 (49.2)	0.70 (0.42, 1.20)
Asian	24 (11.9)	13 (6.4)	2.18 (0.95, 5.04)
Other[c]	19 (9.4)	12 (5.9)	1.65 (0.73, 3.72)
African American	78 (38.4)	78 (38.4)	Reference
Gender			
Boy	84 (41.4)	93 (45.8)	0.84 (0.57, 1.24)
Girl	119 (58.6)	110 (54.2)	Reference
Family income level			
Below 150% of poverty level	122 (73.9)	127 (69.8)	1.42 (0.84, 2.39)
Above 150% of poverty level	43 (26.1)	55 (30.2)	Reference
Peeling paint in home			
Yes	88 (44.0)	68 (33.5)	1.54 (1.03, 2.30)
No	112 (56.0)	135 (66.5)	Reference
Time building of residence constructed			
Before 1950	185 (91.6)	154 (76.6)	3.23 (1.73, 6.02)
1950 or after	17 (8.4)	47 (23.4)	Reference
No. of units in building			
< 3	67 (33.0)	18 (8.9)	6.44 (3.19, 13.02)
≥ 3	136 (67.0)	185 (91.1)	Reference
Frequency at which child puts fingers in mouth			
Sometimes/always	153 (76.1)	120 (59.1)	2.18 (1.39, 3.40)
Never/rarely	48 (23.9)	83 (40.9)	Reference
Child eats nonfood items			
Yes	115 (56.7)	74 (36.5)	2.32 (1.52, 3.53)
No	88 (43.3)	129 (63.5)	Reference

Note. OR = odds ratio; CI = confidence interval. The sample included 203 case–control pairs.
[a]Foreign countries of birth included Haiti (n = 12), Pakistan (n = 7), the Dominican Republic (n = 6), Mexico (n = 5), Puerto Rico (n = 3), India (n = 2), Bangladesh (n = 2), Liberia (n = 2), Ghana (n = 1), Macau (n = 1), Israel (n = 1), Russia (n = 1), Yugoslavia (n = 1), Jamaica (n = 1), Trinidad and Tobago (n = 1), El Salvador (n = 1), Ecuador (n = 1), Colombia (n = 1), and Guyana (n = 1).
[b]Time elapsed between most recent date of residence in a foreign country (for a minimum of 2 months) and date of blood lead testing.
[c]Including White, American Indian, mixed racial background, and "don't know."

TABLE 2—Associations of Foreign Birthplace and Time Elapsed Since Most Recent Foreign Residence With Lead Poisoning Status, Adjusted for Building and Child Behavioral Characteristics: New York City, 2002–2003

	Model 1,[a] OR (95% CI)	Model 2,[b] OR (95% CI)
Foreign born	5.39 (2.15, 13.54)	. . .
Time since most recent foreign residence[c]		
<6 months before blood test	. . .	10.94 (3.28, 36.46)
≥6 months before blood test	. . .	2.92 (1.12, 7.58)
Did not live in a foreign country (Ref)	. . .	1.00
Building characteristics		
Peeling paint in home	1.18 (0.70, 1.98)	1.17 (0.69, 2.00)
Residence in pre-1950 building	2.79 (1.29, 6.03)	3.40 (1.47, 7.84)
Residence in building with fewer than 3 units	5.67 (2.59, 12.41)	5.57 (2.48, 12.52)
Child behavioral characteristics		
Child puts fingers in mouth	2.24 (1.26, 3.97)	2.80 (1.49, 5.24)
Child eats nonfood items	2.10 (1.24, 3.56)	2.02 (1.16, 3.51)

Note. OR = odds ratio; CI = confidence interval.
[a]195 matched pairs.
[b]193 matched pairs.
[c]Time elapsed between most recent date of residence in a foreign country (for a minimum of 2 months) and date of blood lead testing.

foreign birth and residence and lead poisoning status (data not shown).

Other risk factors were also positively associated with lead poisoning status in both multivariate models. Residence in a building with fewer than 3 units (OR=5.6; 95% CI=2.5, 12.5; model 2) and residence in a building constructed before 1950 (OR=3.4; 95% CI=1.5, 7.8) were associated with an increased risk of lead poisoning. In addition, there remained a higher risk of lead poisoning among children who put their fingers in their mouth (OR=2.8; 95% CI=1.5, 5.2) and ate nonfood items (OR=2.0; 95% CI=1.2, 3.5) than among children who did not.

DISCUSSION

We found that, among children tested for lead poisoning, foreign-born children were 5 times more likely than were US-born children to have elevated blood lead levels after adjustment for building characteristics and child behaviors. An even stronger association was found between lead poisoning and recent residence in a foreign country, with children living abroad for less than 6 months before their blood test being 11 times more likely to have elevated blood lead levels than US-born children with no history of foreign residence before their blood test.

We cannot draw definitive conclusions with respect to locations and sources of lead exposure in our sample, particularly because blood lead levels reflect recent exposures as well as past and chronic exposures to lead. The mean biological life of lead in the blood is approximately 30 days[20]; however, after a period of lead exposure, lead is stored in the bone and other tissues in the body and may be released into the blood at a later point in time.[21,22] Therefore, in cross-sectional studies such as ours, blood lead levels alone are not an accurate means of determining the timing and total duration of lead exposures among children. Despite this limitation, we address plausible explanations for and implications of our finding of increased risk associated with spending time in a foreign country.

In the United States, patterns of childhood lead poisoning differ according to socioeconomic position. Similar patterns probably exist across nations, such that in economically depressed countries, where environmental lead is less regulated, children have more opportunities for exposure to lead. In our study, the most common foreign countries of birth among children with lead poisoning were Mexico and countries of the Caribbean and South Asia. Results of an earlier study of elevated blood lead levels among refugee children showed higher prevalence rates among children born in Asian, African, Central American, and Caribbean countries than among children born in the United States or among refugee children from northern Eurasia (e.g., Ukraine, Russia, Germany).[11] In many of these countries, children are likely to be exposed to widespread environmental sources of lead (e.g., leaded gasoline, industrial emissions).[23–26]

Immigrant families' use of lead-contaminated products while living abroad or their continued use of these products in the United States can also increase their children's risk of exposure to lead. Such products include lead-glazed pottery and cookware and lead-contaminated foods, spices, medicines, and cosmetics.[27–32] We asked parents about their use of a limited number of known lead-contaminated products, and only a few reported using them. However, in our experience of providing environmental and educational services for children with lead poisoning, use of potentially contaminated products and food is often underreported, at least partly because of our and families' inadequate knowledge of what products may contain lead. These potential exposure sources are more difficult to identify than lead paint hazards in current housing but may be particularly important in attempting to understand the excess risk observed among immigrant children.

Consistent with the literature, other risk factors for lead poisoning in this study included housing and child behavioral characteristics.[5–8,33] One finding that is unique to our study is the strong association between building size and lead poisoning; New York City children living in buildings with fewer than 3 units were 5 times more likely to have elevated blood lead levels than were children living in larger buildings in the same neighborhoods. The city's local laws addressing lead paint hazards in the homes of young children, in existence since 1982, focus on hazards in large buildings and may be responsible for better control of lead paint hazards in these buildings than in smaller buildings. Additional research in jurisdictions without similar laws can help clarify this relationship. Regardless, our findings suggest that building size may be a useful indicator for targeting primary prevention efforts in New York City.

Limitations and Possible Biases

Our results may have overestimated the increased risk of lead poisoning among immigrant children if other unmeasured factors related to immigration status increased or interacted with exposures to current lead paint hazards. Such factors could include cultural practices (e.g., eating on the floor, leading to an increased possibility of ingesting leaded paint or dust) and preexisting nutritional deficiencies (leading to increased absorption of lead).

We included 5 variables relating to children's household risk of exposure to lead paint hazards (presence of peeling paint in the home, children's mouthing behaviors and ingestion of nonfood items, and building age and size), none of which reduced the magnitude of the associations of lead poisoning with foreign birthplace and time elapsed since most recent foreign residence. Thus, although lead paint–based hazards are the most commonly identified source of childhood lead poisoning in New York City, our results point to the possibility that lead paint and its dust in current housing do not fully explain the increased risk of lead poisoning among immigrant children.

Our assessments of the presence of peeling paint in homes relied on parents' reports of deteriorated paint, and self-reports of such information may be less reliable than data collected through visual inspections by trained professionals. Potential measurement error may have resulted in inadequate control for the risk of lead paint hazards. Furthermore, LPPP inspectors visited the homes of children in the case group but not the control group. Thus, differential misclassification of exposure to lead paint hazards may have occurred if these visits occurred before the study interview, with the result that case families were more likely to know about or recall the presence of deteriorated paint in their homes. Financial restrictions precluded the use of more-reliable methods (e.g., visual inspection by a trained professional, collection of dust samples) of assessing this risk factor.

We cannot rule out the possibility that the biases just described led to overestimation or underestimation of the adjusted relationship between foreign birthplace or foreign residence and risk of lead poisoning. However, our use of a detailed questionnaire and our inclusion of building age as an additional control variable may have mitigated the likelihood of any bias.

To account for potential confounders, we used a pair-matched design and further adjusted for measured confounding variables in our analyses. We chose to match children by their current neighborhood of residence because building characteristics, blood lead levels, and likelihood of undergoing testing vary across New York City neighborhoods.[14] However, because New York City neighborhoods exhibit considerable clustering according to sociodemographic characteristics (e.g., immigration, race/ethnicity, income), this matching strategy may have underestimated the relationship of lead poisoning to these factors.

Overmatching was evidenced by the fact that case and control children resembled each other in terms of socioeconomic status and racial/ethnic background, resulting in our inability to find any significant associations. However, these variables have generally been found to be related to an increased risk of lead poisoning.[34–36] Despite this restriction, our results showed strong associations between lead poisoning and foreign birthplace and recent immigration.

Finally, we cannot rule out that our findings were influenced by selection bias resulting from differences between children receiving and not receiving a blood lead test and between children participating and not participating in the study. Blood lead testing rates in New York City are high, with nearly 88% of children reaching their 3rd birthday in 2004 having undergone at least 1 blood test. New York City children 3 years or older are generally tested on the basis of their level of risk (as ascertained by their health care providers) or in accordance with school requirements. Different results in an unknown direction may have been obtained if tested and untested children had differed in regard to important characteristics related to both their place of birth and residence and their blood lead levels. To lessen the probability of this bias, we matched children on age, neighborhood, and test date, allowing for a degree of comparability in terms of the likelihood of undergoing a blood test.

In addition, 78% of eligible case children but only 49% of eligible control children were enrolled in this study. A multilingual precall letter, multilingual interviewers, and repeated contacts with potential study participants were used to protect against differences in participation rates between the 2 groups.

Public Health Implications

Our findings are consistent with those of other published studies reporting high percentages of immigrants among children with lead poisoning.[9–13] Taken together, these results suggest a need for considering recent immigration as a risk factor for childhood lead poisoning and allocating resources to identify and remove lead exposure sources in the immigrant communities at greatest risk. Public health practitioners and health care providers can contribute to these efforts by learning about common sources of exposure in the populations they serve and educating families of young children about ways to reduce exposures. Although limited, our knowledge of lead-contaminated foods, medicines, and other products is growing (and information and educational materials can be obtained through the Centers for Disease Control and Prevention [http://www.cdc.gov/nceh/lead/faq/FAQs.htm] and through state and local health departments).

Equally important is educating immigrant families about methods of reducing children's exposure to lead paint hazards, given that paint may be an unfamiliar source of exposure for many immigrant communities. Finally, blood lead testing of children who have recently entered the United States from foreign countries in which lead exposure rates are high can facilitate early identification of children exposed to lead and promote timely provision of environmental or medical interventions. ■

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This article was accepted February 26, 2007.

Contributors

P. Tehranifar led the writing of the article. J. Leighton originated and directed all phases of the study. A.H. Auchincloss and A. Faciano participated in study design and implementation. P. Tehranifar, H. Alper, A. Paykin, and S. Wu contributed to analysis and interpretation of data.

Acknowledgments

We thank the project staff for their assistance in data collection and entry.

Human Participant Protection

This study was approved by the institutional review board of the New York City Department of Health and Mental Hygiene. Verbal informed consent was obtained from parents or guardians before interviews were conducted.

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