Lead-Based Paint Health Risk Assessment in Dependent Children Living in Military Housing

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SYNOPSIS

Objective. In children, lead can cause serious permanent damage as a neurotoxicant. The objectives of the study were to evaluate potential exposure to lead-based paint in family housing units at a typical U.S. military installation and determine blood lead (PbB) levels in children ages 6 years or younger residing in these housing units.

Methods. The authors conducted a risk assessment of 1,723 housing units and occupants at Fort Devens in Massachusetts. Data from the military dependent cohort was compared to estimates for the U.S. national population as reported from Phase 1 of the Third National Health and Nutrition Examination Survey (NHANES III).

Results. A total of 1992 individuals (1,009 males and 983 females) were screened for PbB, stratified into age groups, and separated into racial/ethnic categories. Four (0.3%) dust samples and 59 (11.6%) internal and 298 (77.8%) external paint chip samples contained hazardous levels of lead. The geometric mean PbB concentration for people ages 1 year and older reported by NHANES III was 2.8 μg/dL, compared with 1.5 μg/dL for the military installation cohort ($p<0.0001$). PbB levels were higher for males than for females and higher for blacks than whites 6 years of age and older. Hispanics had lower PbB concentrations for all age groups except for those ages 1–2.9 years. Prevalence of PbB levels >10 μg/dL for all age groups was 1.6% in the military cohort, compared with 4.5% for the general population. For ages 1–2.9 years, no blacks or Hispanics and 0.6% of whites had PbB levels >10 μg/dL, compared with 21.6% of blacks, 10.1% of Hispanics, and 8.5% of whites for the general population. For ages 3–5.99 years, 0.15% of blacks, 0% of Hispanics, and 0.3% of whites had PbB levels ≥10 μg/dL, compared with 20.0% of blacks, 6.8% of Hispanics, and 3.7% of whites for the general population.

Conclusion. Lead exposure for occupants of on-post military housing is much less than for those residing in the civilian sector.

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Lead poisoning is the most common disease of environmental origin in the United States. Adult lead toxicity is derived mainly from occupational exposure, whereas pediatric lead toxicity is acquired by ingestion of paint chips, soil, dust, or drinking water as well as eating or drinking from lead-contaminated ceramics, use of lead-contaminated cosmetics, and ingestion of medications. Since the elimination of leaded gasoline emissions, peeling and chalking lead-based paint from residential wall surfaces is now the major source of lead intoxication in children.[1–3] Even at very low doses, lead poisoning can cause developmental neuropsychological impairment.[4–8] Lead toxicity in children can result in poor cognitive performance, behavioral disturbance, learning disability, and low intellectual attainment.[9] In the United States, 1.7 million children younger than 6 years of age were estimated to have blood lead (PbB) levels greater than 10 μg/dL in 1998–1991.[10] Several million more children live in the 21 million contaminated (pre-1950) residential homes with the highest amount of lead-based paint.[11] These same children, unfortunately, possess many of the risk factors that exacerbate the manifestations of lead toxicity, such as low socioeconomic status and low iron and calcium intake.[12] Public health measures to combat the lead threat include remediation and cleanup of lead-contaminated buildings, intensive national urban screening programs, case-finding efforts, and medical case treatment and follow-up activities, in addition to education programs. Despite a decline in air lead levels and mean PbB levels in the U.S. population, residual lead contamination in dust and soil remain high due to accumulation of lead from decades of unrestricted lead use in paint and gasoline.

The objectives of this study were to evaluate the potential exposure to lead-based paint in family housing units at a typical military installation in the continental United States and to determine current PbB levels in residents of these housing units, with primary emphasis placed upon children age 6 years or younger. It was anticipated that PbB levels would be lower than in concurrent national data, from the Third National Health and Nutrition Examination Survey (NHANES III),[10] due to good maintenance and thorough abatement procedures that reduce potential exposure.

METHODS

Study site

A lead toxicity risk assessment of 1,723 family housing units located on Fort Devens in Massachusetts was conducted from June through August 1991. The guidelines for the assessment method were taken from Section 2.3, "Setting Priorities for Abatement," of the U.S. Department of Housing and Urban Development's (HUD) *Lead-Based Paint: Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing*.[13] Risk factors associated with the building (housing factors) as well as risk factors associated with the families occupying the building (occupant factors) were considered. Housing factors include age of the structure and condition of painted surfaces. Occupant factors include presence of and number of children, age of the mother, children with elevated PbB levels, and occupant housekeeping practices. A structured questionnaire was utilized to document and categorize the data required for estimating the potential exposure to the occupant. This assessment generated a rating of low, medium, or high potential.

Floor dust samples were collected from the interior of each housing unit, and paint chip samples were collected from interior and exterior surfaces exhibiting peeling paint. Analysis of lead content in these samples was performed by the U.S. Army Environmental Hygiene Agency.

Family housing dust sampling procedure

Dust samples were collected by the assessors during a walk-through risk assessment of each housing unit by the wipe sampling method in accordance with Section A-5.4.1, "Wipe Sampling Procedure," of *Lead-Based Paint: Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing*.[13] Samples were taken from a well-traveled floor area such as a hallway or kitchen of a smooth surface type (e.g., wood, tile, linoleum). The chosen sampling location exhibited some evidence of dust build-up, was not in an isolated area, and was representative of the general conditions of the housing unit. Briefly, a plastic template measuring 1 ft^2 was used to define the sampled floor area. Dust was collected from the area within the template using premoistened filter wipes (Wash-Abye-Baby, Scott Paper Company, as recommended by the Childhood Lead Poisoning Prevention Program, Massachusetts Department of Public Health). One field blank sample was prepared by the assessment team supervisor each environmental sampling day and treated exactly as the true sample wipes for shipping and analysis.

At the time of this risk assessment, HUD's Interim Guidelines, Section 10.4.3,[13] and Massachusetts 105 CMR 460.170[14] established maximum lead level standards in house dust as 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills, and 800 $\mu g/ft^2$ for window wells. Floor dust standards were reduced to 100 $\mu g/ft^2$ in 1995 and further reduced to 40 $\mu g/ft^2$ in 2000.[15,16]

Lead content in dust samples was determined by an atomic emissions instrument by a method that conformed to the HUD Interim Guidelines.[13] The detection limit was <1 μg/sample.

Family housing paint chip sampling procedure

Paint chip samples were collected by the assessor during the walk-through risk assessment of each housing unit. Paint chip samples were collected from peeling painted surfaces, including all woodwork, walls, and ceilings. If more than one type of surface exhibited signs of peeling paint, then the assessor collected a sample from each type. For example, if paint was peeling from several plaster surfaces such as ceilings or walls in the bedroom and living room, only one sample was taken. If, in addition, paint was peeling from several areas of woodwork, doors, or pieces of trim, then a second sample was collected from one of the areas of woodwork. Exterior samples were also collected if peeling paint was readily accessible to the assessor. The assessor only collected peeling chips of paint and did not scrape any from surfaces that were not peeling.

HUD Interim Guidelines, Section 1.1, and Massachusetts 105 CMR 460.020 were used for the lead level standard in paint chips (0.5% by weight).[13,14] The lead content of the paint chips was determined by atomic emissions. The method used conformed to the HUD Interim Guidelines.[13]

Blood testing program

Peripheral blood samples used for the determination of PbB were collected at the Cutler Army Hospital Department of Pediatrics, supplemented by a two-week phlebotomy clinic in June 1991 staffed by soldiers assigned to the 363rd Medical Laboratory. Additional PbB levels from 1990 were obtained from patient records and included in the dataset. These data accounted for approximately 35% of all children ages 6 and younger who lived at Fort Devens in 1990–1991.

Statistical analysis

Differences in sample means were compared using Student's *t*-test. The standard deviations for the national population sample (NHANES III) data was unavailable. Assuming the samples came from the same normally distributed population, the standard deviation derived from the Fort Devens cohort was assumed to be equal to that of the national population and used for the *t*-test calculations. Analysis of variance comparisons were made between PbB, dust lead, and paint lead levels.

RESULTS

Population characteristics

A total of 1,992 individuals, consisting of 1,009 males and 983 females, had PbB concentration determinations during the period of the risk assessment. Age was recorded for 1,955 subjects; race/ethnicity was identified only in 736 subjects due to patient confidentiality policies. Self- or parent-identified race/ethnicity was divided into three categories: white (513), black (124), Hispanic (59), and other (40).

Though the risk assessment investigation was directed at dependent children, no family member was denied a PbB concentration determination. Age was stratified into seven categories: Group 1, <1 year old; Group 2, 1–2.99 years; Group 3, 3–5.99 years; Group 4, 6–11.99 years; Group 5, 12–19.99 years; Group 6, 20–44.99 years; Group 7, ≥45 years old. Housing risk categories were obtained for 1,767 dependents. There were 1,739 individuals with PbB determinations who also had age and housing risk status recorded.

PbB levels

Geometric means and standard deviations are presented by age category in Table 1. Data from this cohort of children are compared to concurrent na-

Table 1. Sample size, geometric mean, and geometric standard deviation of blood lead levels by age category for Fort Devens cohort

Age group (years)	*Number*	*Geometric mean (μg/dL)*	*Geometric standard deviation*
Group 1 (<1)	490	1.5	2.655
Group 2 (1–2.9)	417	1.8	2.805
Group 3 (3–5.9)	903	1.3	2.655
Group 4 (6–11.9)	120	1.3	2.904
Group 5 (12–19.9)	6	1.4	1.786
Group 6 (20–44.9)	18	2.3	2.307
Group 7 (≥45)	1	3.0	—
Total	1992	1.5	2.716

Table 2. Weighted geometric means and 95% CIs of blood lead levels for individuals ages 1 year and older by age category, United States, 1988–1991

Age (years)	*Number*	*Population estimate (thousands)*	*Geometric mean (μg/dL)*	*95% CI (μg/dL)*
1–2	925	7,476	4.1	3.7, 4.5
3–5	1,309	11,165	3.4	3.0, 3.8
6–11	1,587	21,748	2.5	2.2, 2.7
12–19	1,376	27,293	1.6	1.4, 1.9
20–49	4,320	112,283	2.6	2.5, 2.8
50–69	2,071	42,802	4.0	3.8, 4.2
≥70	1,613	19,440	4.0	3.7, 4.3
All	13,201	242,207	2.8	2.7, 3.0

SOURCE OF DATA: Reference 10.

CI = confidence interval

tional population estimates for each age group obtained by NHANES III.[10] The national average weighted geometric mean and 95% confidence intervals for each age category for 1988–1991 are presented in Table 2.

The geometric mean PbB levels for Age Groups 2, 3, and 4 for the Fort Devens cohort are approximately 50% of the levels in the general population, whereas the geometric mean blood levels approximate those of the general population for Age Groups 5–7. Differences between the population means using Student's *t*-test were statistically significant ($p \leq 0.0001$) for all age groups combined and for Age Groups 2–4 compared individually. The Fort Devens sample size in Age Groups 5–7 was too small to compare with the national population for those age categories.

PbB levels by sex, age, and race/ethnicity

Mean PbB levels varied by gender, age, and race/ethnicity. Table 3 demonstrates similarities in PbB concentrations between males and females younger than 6 years of age (Age Groups 1–3). Beginning at Age Group 4 (6–11.99 years of age), the geometric mean PbB levels for males were approximately 0.1 μg/dL higher than those for females. The difference increased to 0.8 μg/dL higher for males than for females in Age Group 5 (12–19.99 years of age). Table 4 demonstrates that mean PbB levels for whites and blacks were similar until 6 years of age (Age Groups 1–3). The geometric mean PbB level for blacks ages 6–11.99 (Age Group 4) was 0.5 μg/dL higher than that for whites in the same age group. PbB levels for Hispanics were lower

Table 3. Descriptive statistics for Fort Devens cohort stratified by age category and gender

Age group (years), gender	*Number*	*Geometric mean (μg/dL)*	*Geometric standard deviation*
Group 1 (<1), male	239	1.5	2.636
Group 1 (<1), female	251	1.5	2.679
Group 2 (1–2.9), male	209	1.8	2.792
Group 2 (1–2.9), female	208	1.8	2.818
Group 3 (3–5.9), male	464	1.3	2.679
Group 3 (3–5.9), female	439	1.3	2.630
Group 4 (4–11.9), male	66	1.4	3.090
Group 4 (4–11.9), female	54	1.3	2.698
Group 5 (12–19.9), male	2	2.0	0
Group 5 (12–19.9), female	4	1.2	1.941
Group 6 (20–44.9), male	8	3.2	1.596
Group 6 (20–44.9), female	10	1.8	2.698
Group 7 (≥45), male	0	—	—
Group 7 (≥45), female	1	3.0	—
Total	1992	1.5	2.716

than those for blacks and whites in Age Groups 1, 3, and 4 and the levels for whites and blacks were equivalent in Age Group 2.

Prevalence of elevated PbB levels

The overall prevalence of PbB levels ≥10 µg/dL for all Age Groups in the Fort Devens cohort was 1.6%, compared with 4.5% for the general population.[10] The overall prevalence of PbB levels ≥10 µg/dL for Age Groups 1–4 was 1.9%. The prevalence of elevated PbB levels was 0.4% for Age Group 2 (vs. 11.5% for the general population), 0.5% for Age Group 3 (vs. 7.3% for the general population), and 0.2% for Age Group 4 (vs. 4.0% for the general population). Analyses stratified by race/ethnicity revealed that there were no blacks or Hispanics in Age Group 2 (1–2.99 years old) with PbB levels ≥10 µg/dL and that 0.6% of whites in Age Group 2 had PbB levels ≥10 µg/dL, compared with 21.6% of blacks, 10.1% of Hispanics, and 8.5% of whites in this age group in the general population. For Age Group 3 (3–5.99 years of age), 0.15% blacks, no Hispanics, and 0.3% of whites had PbB levels ≥10 µg/dL vs. 20.0% of blacks, 6.8% of Hispanics, and 3.7% of whites in the general population.

Risk assessment survey results

The results of the survey indicate the potential for lead exposure contributed by lead-based paint in military housing to be relatively low. Of the 1,723 housing units surveyed, 68.6% had a low potential, 31.0% had a medium potential, and 0.4% had a high potential for exposure to lead. The exterior and interior conditions of family housing units were well maintained with limited amounts of peeling paint.

Dust and paint lead analysis results

Paint chip and dust sample analysis indicated that the use of lead-based paint was widespread, with varying levels of lead. Fifty-nine of 509 (11.6%) paint chip samples collected from internal surfaces and 298 of 383 (77.8%) paint chips collected from external surfaces exceeded the minimum acceptable percentage of lead concentration (0.5% by weight). In the 1,198 housing units where individuals resided for whom PbB concentrations were obtained, 38 (11.5%) of the 330 interior paint chips samples analyzed and 192 (80.0%) of the 240 exterior paint chips analyzed contained hazardous levels of lead.

None of the dust samples (mean = 2.3 µg lead/ft^2; $n = 1303$) from any housing unit at Fort Devens exceeded 200 µg lead/ft^2, the standard for floor lead dust levels in effect at the time of the risk assessment.[13,14] Four dust samples (49, 69, 110, and 150 µg lead/ft^2) exceeded the current standard of 40 µg lead/ft^2.[16] Neither dust lead loading measurements, interior paint lead concentrations, exterior paint lead concentrations,

Table 4. Descriptive statistics of Fort Devens cohort stratified by age category and race/ethnicity

Age group (years), race/ethnicity	*Number*	*Geometric mean (µg/dL)*	*Geometric standard deviation*
Group 1 (<1), black	27	2.0	2.388
Group 1 (<1), Hispanic	15	1.2	1.905
Group 1 (<1), white	118	2.3	2.173
Group 2 (1–2.9), black	31	2.3	2.421
Group 2 (1–2.9), Hispanic	14	2.2	2.188
Group 2 (1–2.9), white	129	2.1	2.541
Group 3 (3–5.9), black	55	2.1	2.673
Group 3 (3–5.9), Hispanic	24	1.6	2.443
Group 3 (3–5.9), white	233	1.9	2.399
Group 4 (4–11.9), black	9	2.4	3.412
Group 4 (4–11.9), Hispanic	4	1.3	3.090
Group 4 (4–11.9), white	28	1.9	3.048
Group 5 (12–19.9), black	1	0.5	—
Group 5 (12–19.9), Hispanic	2	2.0	0
Group 5 (12–19.9), white	0	—	—
Group 6 (20–44.9), black	0	—	—
Group 6 (20–44.9), Hispanic	0	—	—
Group 6 (20–44.9), white	2	1.7	2.173
Total	696	2.0	2.438

nor overall housing risk potential demonstrated statistically significant comparisons to PbB levels ($p>0.32$) in the individuals tested by analysis of variance.

DISCUSSION

Geometric mean PbB concentrations for children younger than 20 years of age living in housing units within the Fort Devens U.S. Army post perimeter were essentially equivalent (1.5, 1.8, 1.3, 1.3, and 1.4 μg/dL PbB respectively for Age Groups 1–5), demonstrating a uniform background exposure to lead. Children residing in on-post housing are dependents of military personnel, and virtually all have lived since birth in housing maintained by the Department of the Army. Geometric mean PbB concentrations in the Fort Devens cohort for Age Groups 2–4 (ages 1–11.99) were one-half or less of the PbB levels in the general population as reported by NHANES III, Phase 1 (1988–1991). Absence of elevated PbB levels in the children is a reliable indicator of low exposure, attributable to the lack of hazardous levels of lead in dust samples and good conditions of exterior and interior residential building surfaces. Potential toxic sources of exposure are limited more aggressively within a military installation than are equivalent sources in the civilian sector.

Racial/ethnic differences in PbB levels in the Fort Devens cohort did not mimic those of the general population. Whites, blacks, and Hispanics had similar geometric mean PbB levels for Age Groups 2–4, albeit one-third to one-half those of the general population for respective racial/ethnic and age categories.

There are several limitations in this study that should be acknowledged. First, race/ethnicity was identified only in 736 subjects because medical records personnel at the Cutler Army Hospital, citing patient confidentiality, withheld that information. Secondly, elimination of lead exposure by other unmeasured sources was not possible. Third, nutritional factors affecting lead absorption, such as dietary calcium intake, were not measured. Fourth, variables such as mouthing behavior of the children, length of time living in the housing, amount of lead content in soil and water, were not documented. Floor dust samples were collected only from well-traveled non-carpeted areas; no dust samples were collected from interior window sills and window wells.

Although limited local variations exist, in general, standard architecture and maintenance practices, as directed by the Department of Defense, are universal for family housing on military installations. The presence of good exterior and interior surfaces was a direct result of the Directorate of Engineering and Housing and the Self Help maintenance programs at Fort Devens. Potential for exposure to underlying layers of lead-based paint was markedly reduced by abatement through these maintenance programs. The lack of hazardous levels of lead in dust samples can be attributed to the thorough and vigorous housecleaning procedures used by post engineers when quarters are vacated, in addition to the strict enforcement of good interior housecleaning practices by the occupants while residing in each housing unit.

Lead accumulation in dust and soil from past atmospheric deposition and from deteriorating housing containing lead-based paint is the primary long-term repository and major contributor of overall lead exposure in children.[17] One of the most effective primary intervention measures to reduce lead exposure appears to be adequate lead abatement and satisfactory maintenance of older housing.[18] The absence of dangerous levels of lead in dust samples in the housing units of Fort Devens is a key factor for the lower PbB concentrations of the occupants since dust lead is a significant source of lead in children.[18–20]

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