



Blood Lead Levels in U.S. Children Ages 1-11 years, 1976-2016

Lead Exposure and Prevention Advisory Committee (LEPAC) meeting

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Background

- **No safe level of blood lead has been identified for children.**
- **Many factors affect how the body handles foreign substances such as lead exposures:**
 - source of exposure, length of exposure, child's age, nutritional status, and genetics.
- **A blood test measures the level of lead in the blood which can indicate exposure.**

How are U.S. children exposed to lead?

- **Deteriorating lead-based paint in older homes and buildings is the most common source.**
 - accounts for up to 70% of elevated childhood BLLs
 - lead dust and paint chip hazards are of concern
- **Home renovations can disturb lead paint.**
- **Sources transported inside from outdoors**
 - soil and exterior paint
- **Transferred from surfaces to hands and ingested by young children via normal hand-to-mouth activity.**

How are U.S. children exposed to lead? (continued)

- **Less common sources include:**
 - unintentional take-home lead exposure from a worksite
 - lead-contaminated water
 - traditional folk medicines and cosmetics
 - imported candy and candy wrappers
 - some imported spices
 - some imported toys
 - Herbal remedies
 - cookware from international manufacturers



Risk to children

- **Children have greatest risk of exposure and adverse health effects.**
 - unique behavioral factors such as mouthing and crawling
 - developing body systems and detoxification processes
 - children absorb more lead per body size

- **Lead can permanently impair cognitive abilities and cause other health effects—yet a child may not show evident signs or symptoms.**



**Our Analysis:
Blood Lead Levels in U.S. Children Ages 1-11 years,
1976-2016**

Background

- **BLL have declined over time which has largely been achieved through public health efforts and federal regulations, including:**
 - the removal of lead from gasoline
 - the ban of lead-based paint
 - the ban of lead plumbing solder for residential uses
- **Recent high-profile events, such as the Flint Water Crisis, have highlighted ongoing sources of lead exposure in children.**

Our Aim

- **To describe the distribution of BLLs in U.S. children ages 1-5 years and 6-11 years by selected sociodemographic and housing characteristics over a 40 year period from 1976-2016.**
- **To date, there has been no comparable analyses of BLLs in children over the entire 40 year period.**

The National Health and Nutrition Examination Survey (NHANES)

- **NHANES is a nationally representative, cross-sectional survey of the resident civilian noninstitutionalized U.S. population that has assessed lead exposure for the U.S. population since 1976.**
- **NHANES is designed to monitor the nation's health and nutritional status.**
- **Prior to 1999, NHANES was conducted on a periodic basis.**
 - NHANES II (1976-1980)
 - NHANES III (Phase I: 1998-1991 and Phase II: 1991-1994)
- **Since 1999, NHANES has been conducted in 2-year continuous cycles.**
- **NHANES collects venous whole blood specimens from participants ≥ 1 year.**

Survey Cycles

- **We assessed BLLs using NHANES data.**
- **Survey cycles were grouped into 4-y or 6-y categories:**
 - NHANES II (1976-1980)
 - NHANES III Phase 1 (1988-1991)
 - NHANES III Phase 2 (1991-1994)
 - NHANES 1999-2002
 - NHANES 2003-2006
 - NHANES 2007-2010
 - NHANES 2011-2016

Demographic Characteristics Included

- **Age: 1-5y and 6-11y**
- **Race/ethnicity:**
 - Non-Hispanic White
 - Non-Hispanic Black
 - Mexican American
 - Other Hispanic
 - Other race
- **Birthplace:**
 - United States
 - Mexico
 - Other
- **Family income to poverty ratio (FIPR):**
 - Ratio of total family income to the federal poverty threshold and stratified as <1.3 and ≥1.3
- **Health insurance coverage (yes/no)**
- **Medicaid status (yes/no)**
- **Participation in WIC (yes/no)**
- **Housing age:**
 - NHANES III pre-1946, 1946-1972, 1973 to present, and unknown
 - NHANES 1999-2010 pre-1950, 1950-1977, 1978 to present, and unknown
- **Note:**
 - Not all variables were assessed in each survey cycle
 - Variable definitions sometimes changed over time

Geographic Variables Included

- **Urbanization**
- **Geographic region**
 - Northeast, Midwest, South and West
 - Regional estimates cannot be directly compared across surveys
- **Assessed at the Research Data Center (RDC):**
 - All geography below the national level is restricted for continuous NHANES due to disclosure risk
 - All geography below the regional level is restricted prior to 1999

Methods

- **The distribution of BLLs in U.S. children ages 1-5 and 6-11 y was assessed for all children with valid BLLs.**
- **Estimates calculated include:**
 - Weighted geometric mean (GM) BLLs (95% CI)
 - Weighted estimated prevalence of $\text{BLL} \geq 5 \mu\text{g/dL}$ (95% CI) or $\text{BLL} \geq 10\mu\text{g/dL}$
- **Estimates were calculated overall and by selected characteristics, stratified by age group (1-5 y and 6-11 y).**

Points to Note

- **Estimates were produced using the examination sampling weight.**
- **The cluster design was accounted for in estimating variances.**
- **Prevalence estimates that had a relative standard error (RSE) of the estimate $\geq 30\%$ were regarded as statistically unreliable.**
- **All results of cell count sample sizes < 5 or percentages calculated from numerators < 5 were suppressed due to disclosure concerns.**
- **Formal statistical testing for differences in BLLs for each variable of interest was not completed.**

What did we find?

Results

- **27,122 children had valid BLLs over the selected time period.**
- **Ages 1-5 years:**
 - GM BLL declined from 15.2 $\mu\text{g}/\text{dL}$ (CI 14.3, 16.1) in 1976-1980 to 0.83 $\mu\text{g}/\text{dL}$ (CI 0.78, 0.88) in 2011-2016
 - A 94.5% decrease over time
- **Ages 6-11 years:**
 - GM BLL declined from 12.7 $\mu\text{g}/\text{dL}$ (CI 11.9, 13.4) in 1976-1980 to 0.60 $\mu\text{g}/\text{dL}$ (CI 0.58, 0.63) in 2011-2016
 - A 95.3% decrease over time
- **Higher GM BLLs were associated with:**
 - non-Hispanic Black race/ethnicity
 - lower family income-to-poverty-ratio
 - older housing age

Figure 1. Geometric mean BLL for children ages 1-5 y and ages 6-11 y in the NHANES, 1976-2016, by survey cycle

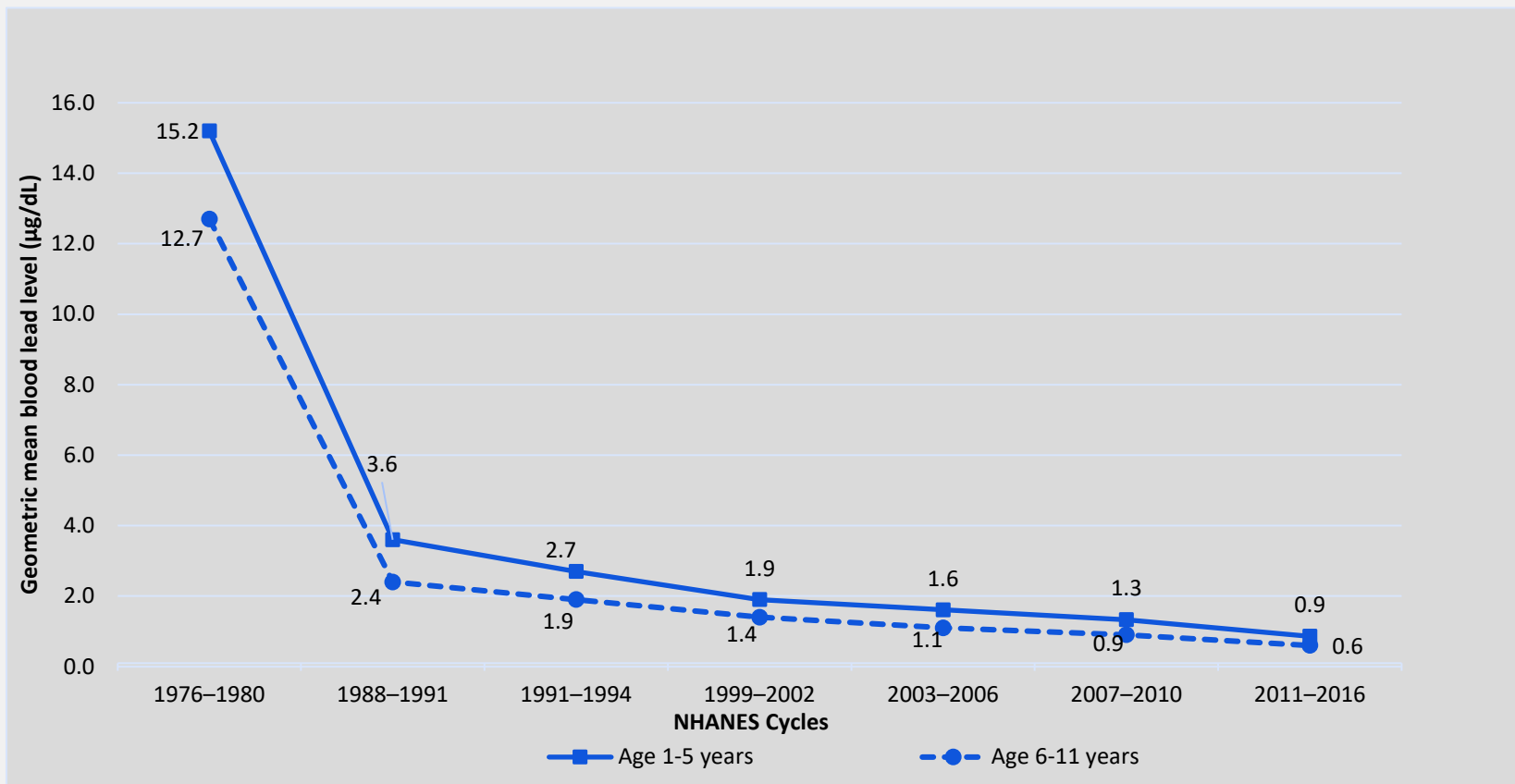


Figure 2. Estimated prevalence (%) of BLLs ≥ 10 $\mu\text{g}/\text{dL}$ or ≥ 5 $\mu\text{g}/\text{dL}$ among U.S. children ages 1-11 y, 1976-2016, by survey cycle

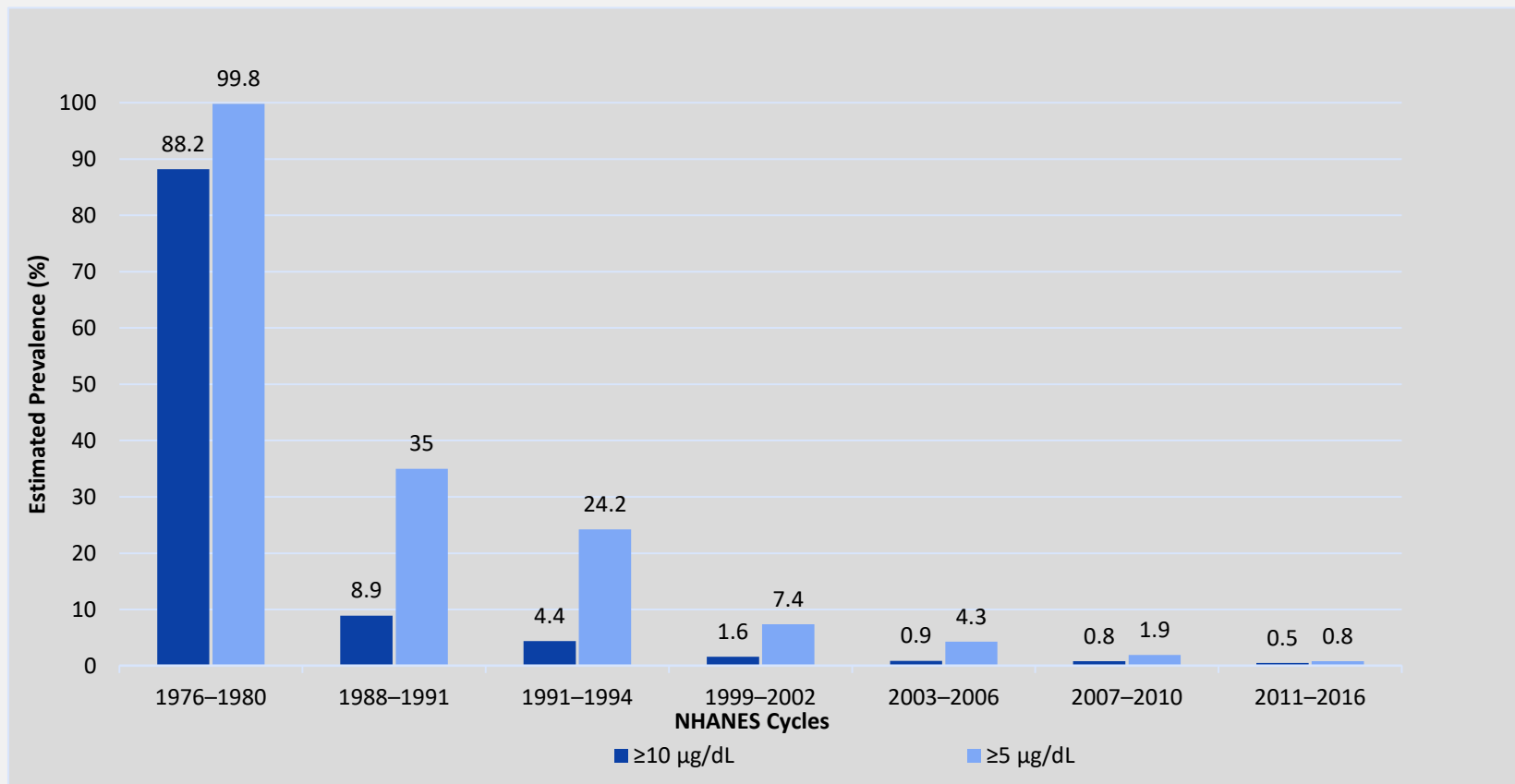


Table 1. Population estimate (N), total participants (N), and participants (N, %) with valid blood lead level (BLL) from among U.S. children (N) ages 1-11 years, and weighted estimates for prevalence (%) and 95% confidence interval (CI) of BLL \geq 5 μ g/dL and number of children with BLL \geq 5 μ g/dL, by survey cycle (years) and age group (1-5 y and 6-11 y) in the National Health and Nutrition Examination Survey (NHANES), 1976-2016.

Survey Cycle	Population Estimate	Total Participants	Ages 1-5 y			Ages 6-11 y				
			Participants with valid BLL	BLL \geq 5 μ g/dL	BLL \geq 5 μ g/dL	Population Estimate	Total Participants	Participants with valid BLL	BLL \geq 5 μ g/dL	BLL \geq 5 μ g/dL
Years	N	N	N (%)	% (95% CI) ^a	N	N	N (%)	% (95% CI) ^a	N	
1976-1980	15,263,000 ^b	3,762	2,360 (62.7)	99.8 (99.4, 99.9)	15,232,474	20,880,000 ^b	1,725	830 (48.1)	99.7 (98.6, 99.9)	20,817,360
1988-1991	19,657,453 ^c	3,278	2,232 (68.1)	31.4 (26.0, 37.3)	6,172,440	22,527,176 ^c	1,943	1,584 (81.5)	15.0 (11.3, 19.7)	3,379,076
1991-1994		2,876	2,392 (83.2)	21.0 (16.0, 27.0)	4,128,065		1,524	1,345 (88.3)	9.5 (7.3, 12.2)	2,140,082
1999-2002	19,323,164 ^d	2,415	1,621 (67.1)	8.7 (6.5, 11.5)	1,681,115	24,889,987 ^d	2,355	1,949 (82.8)	3.0 (1.9, 4.6)	746,700
2003-2006	20,257,887 ^e	2,677	1,879 (70.2)	4.1 (2.9, 5.8)	830,573	23,921,965 ^e	2,179	1,790 (82.1)	1.3 (0.7, 2.6) ^h	310,986
2007-2010	20,870,073 ^f	2,526	1,653 (65.4)	2.6 (1.7, 4.2)	542,622	24,055,655 ^f	2,519	2,020 (80.2)	0.4 (0.2, 0.8)	96,223
2011-2016	20,171,918 ^g	3,609	2,321 (64.3)	1.3 (0.7, 2.4) ^h	262,235	24,707,984 ^g	4,031	3,146 (78.0)	0.5 (0.1, 0.5) ^h	123,540

a. Weighted estimates derived from the observed data for the study population using NHANES-specified sampling weights.

b. NHANES II: U.S. Non-institutionalized population as of March 1, 1978 (approximate midpoint of the survey); from the U.S. Census Current Population Survey.

c. NHANES III: U.S. population from combined 6-year sample, NHANES III data file, 1988-1994; from the U.S. Census Bureau Current Population Survey.

d. Continuous NHANES 1999-2002: Distribution of the civilian noninstitutionalized U.S. population for the midpoint of 1999-2002; from the U.S. Census Bureau Current Population Survey.

e. Continuous NHANES 2003-2006: Distribution of the civilian noninstitutionalized U.S. population for the average of 2003-04 and 2005-06 cycles; from the U.S. Census Bureau American Community Survey.

f. Continuous NHANES 2007-2010: Distribution of the civilian noninstitutionalized U.S. population for the average of 2007-08 and 2009-10 cycles; from the U.S. Census Bureau American Community Survey.

g. Continuous NHANES 2011-2016: Distribution of the civilian noninstitutionalized U.S. population for the average of 2011-12, 2013-14, and 2015-16 cycles; from the U.S. Census Bureau American Community Survey.

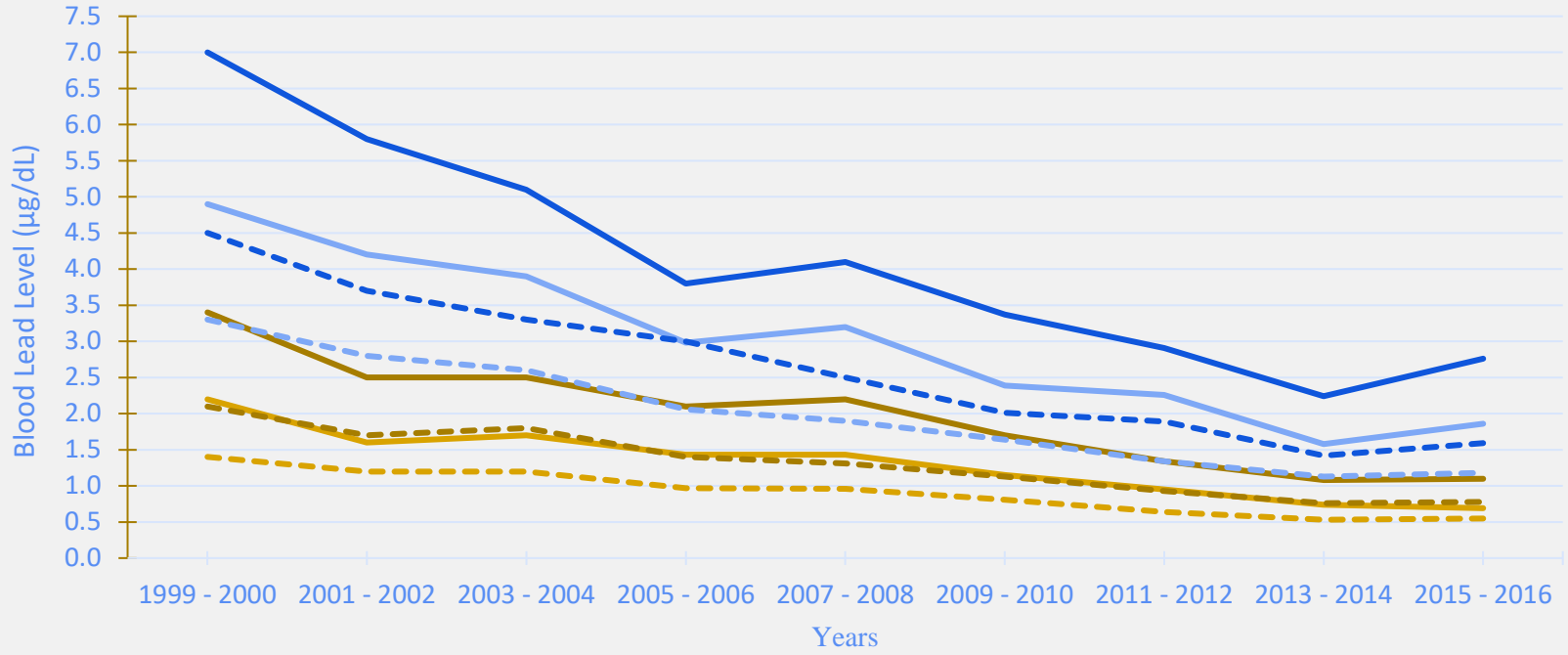
h. Relative Standard Error (RSE) greater than or equal to 30% indicates estimate is statistically unreliable.

Drill down of Table 1:

Population estimate, total participants, and participants with valid blood lead level from among U.S. children ages 1-11 years, and weighted estimates for prevalence

Survey Cycle	Population Estimate	Total Participants	Ages 1-5 y			Ages 6-11 y				
			Participants with valid BLL	BLL ≥5 µg/dL	BLL ≥5 µg/dL	Population Estimate	Total Participants	Participants with valid BLL	BLL ≥5 µg/dL	BLL ≥5 µg/dL
Years	N	N	N (%)	% (95% CI) ^a	N	N	N (%)	% (95% CI) ^a	N	
1976-1980	15,263,000 ^b	3,762	2,360 (62.7)	99.8 (99.4, 99.9)	15,232,474	20,880,000 ^b	1,725	830 (48.1)	99.7 (98.6, 99.9)	20,817,360
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2011-2016	20,171,918 ^g	3,609	2,321 (64.3)	1.3 (0.7, 2.4) ^h	262,235	24,707,984 ^g	4,031	3,146 (78.0)	0.5 (0.1, 0.5) ^h	123,540

Figure 3. Selected percentiles of BL concentrations for U.S. children ages 1-5 y and ages 6-11 y in the NHANES, 1999-2016 by two-year survey cycle



Ages 1-5 — 95th percentile — 90th percentile — 75th percentile — 50th percentile
 Ages 6-11 - - - 95th percentile - - - 90th percentile - - - 75th percentile - - - 50th percentile

Discussion

- Overall, BLLs in U.S. children ages 1-11 y have decreased substantially over the past 40 years.
- Higher GM BLLs are consistently associated with risk factors, such as race/ethnicity, poverty, and housing age, that can be used to target blood lead screening efforts.
- Our analyses indicate that significant progress has been made in reducing the number of children with elevated BLLs.
- Despite these notable declines in population exposures to lead over time, an estimated 385,775 children ages 1-11 y had BLLs ≥ 5 $\mu\text{g}/\text{dL}$ (NHANES 2011-2016).

Discussion (continued)

- **Virtually all children had BLLs ≥ 5 $\mu\text{g}/\text{dL}$ in 1976-1980.**
- **In 2011-2016, the estimated prevalence of BLLs ≥ 5 $\mu\text{g}/\text{dL}$ was $<2\%$ of children ages 1-5 y and $<1\%$ of those ages 6-11 years.**
- **A portion of children, particularly those of minority and low-income backgrounds, still have a higher estimated prevalence of BLL ≥ 5 $\mu\text{g}/\text{dL}$.**
- **Income level and older housing are risk factors:**
 - for older children (age 6-11 y) as well as younger (age 1-5 y)
 - that have persisted over time

Limitations

- **Sample size:**
 - The population subsample of children with valid BL results is limited
 - No ability to conduct detailed subgroup or multivariate analyses due to small cell sizes at elevated BLLs
 - Estimates with RSE >30% are considered statistically unstable and should be reviewed with caution
- **NHANES cannot determine the specific source(s) of lead exposure for surveyed children.**

Limitations (continued)

- **Missing data:**

- Over 20% of all children ages 1-11 y sampled in NHANES were missing BLLs during the 40-y analysis period.
- Missing BLL data among participants could potentially bias estimates if these children had different exposure risks compared with those who were tested.

- **Differential response bias:**

- Potential for bias due to differential response rates by age (1-5 y and 6-11 y) since age is related to lead exposure

Conclusion

- **Given the detrimental health effects and long-term impacts of lead exposure in children, creating lead-safe environments for all children is critical.**
- **Continued, coordinated public health effort at national, state, and local levels can build on past achievements and provide lead-safe environments for all children.**
- **For more information:**
 - Egan KB, Cornwell CR, Courtney J, and Ettinger A. 2021. Blood Lead Levels in U.S. Children Ages 1-11 years, 1976-2016. *Environ Health Perspect.* 129(3):37003. DOI: 10.1289/EHP7932.

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- **NCEH Division of Laboratory Sciences**

For more information on lead poisoning prevention:

CDC Childhood Lead Poisoning Prevention Program (CLPPP)

<https://www.cdc.gov/nceh/lead/>

Email: lppp@cdc.gov

For more information, contact NCEH

1-800-CDC-INFO (232-4636)

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