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)
- 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 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
- **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 BLL ≥5 µg/dL (95% CI) or BLL ≥ 10µg/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 ≥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 µg/dL (CI 14.3, 16.1) in 1976-1980 to 0.83 µg/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 µg/dL (CI 11.9, 13.4) in 1976-1980 to 0.60 µg/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 µg/dL or ≥5 µg/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 ≥5 µg/dL and number of children with BLL ≥5 µg/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.

<table>
<thead>
<tr>
<th>Survey Cycle</th>
<th>Population Estimate</th>
<th>Total Participants</th>
<th>Participants with valid BLL</th>
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<tbody>
<tr>
<td>Ages 1-5 y</td>
<td>N</td>
<td>N</td>
<td>N (%)</td>
<td>% (95% CI)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>N</td>
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<tr>
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<td>2011-2016</td>
<td>20,171,918&lt;sup&gt;g&lt;/sup&gt;</td>
<td>3,609</td>
<td>2,321 (64.3)</td>
<td>1.3 (0.7, 2.4)&lt;sup&gt;h&lt;/sup&gt;</td>
<td>262,235</td>
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<tr>
<td>Ages 6-11 y</td>
<td>N</td>
<td>N</td>
<td>N (%)</td>
<td>% (95% CI)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>N</td>
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<tr>
<td>1976-1980</td>
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<td>1,725</td>
<td>830 (48.1)</td>
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<sup>a</sup> Weighted estimates derived from the observed data for the study population using NHANES-specified sampling weights.

<sup>b</sup> 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.


<sup>e</sup> 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.

<sup>f</sup> 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.

<sup>g</sup> 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.

<sup>h</sup> 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

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| **Ages 6-11 y** |                     |                    |                             |              |              |                     |                    |                             |              |              |
| 1976-1980    |                     |                    |                             |              |              |                     |                    |                             |              |              |
| 1988-1991    |                     |                    |                             |              |              |                     |                    |                             |              |              |
| 1991-1994    |                     |                    |                             |              |              |                     |                    |                             |              |              |
| 1999-2002    |                     |                    |                             |              |              |                     |                    |                             |              |              |
| 2003-2006    |                     |                    |                             |              |              |                     |                    |                             |              |              |
| 2007-2010    |                     |                    |                             |              |              |                     |                    |                             |              |              |
| 2011-2016    |                     |                    |                             |              |              |                     |                    |                             |              |              |

*a* = note: BLL = blood lead level

Note: BLL ≥5 µg/dL is the prevalence of blood lead level ≥5 µg/dL among children ages 1-11 years.
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
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 µg/dL (NHANES 2011-2016).
Discussion (continued)

- In 2011-2016, the estimated prevalence of BLLs ≥5 µg/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 µg/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:
Acknowledgments

- **Co-Authors:**
  - Cheryl Cornwell
  - Joseph Courtney
  - Adrienne Ettinger

- **Research Data Center**
  - Wanjun (June) Cui – RDC Analyst

- **NHANES staff and the National Center for Health Statistics**

- **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