Variability and trajectory of multiple blood lead measures among construction and manufacturing workers

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Background

• ABLES is a rich data source with multiple measures
• Variable time scales:
  – Biological
  – Regulatory
  – Captured by surveillance
• How do we best characterize exposure to represent true risk from chronic lead exposure?
• How frequently should we conduct biological measures of lead exposure?
Absorption & Kinetics

• Absorption and Kinetics strongly affected by host characteristics such as age, nutritional status, and pre-existing health status
  – Conditions of high calcium demand (e.g. breastfeeding, pregnancy)
  – Conditions of bone loss (e.g. osteoporosis)
  – Conditions of iron or calcium deficiency

• Ingestion Route
  – Adults ~10% absorption whereas Children ~50% absorption
    • Adults excrete via biliary route 50% of that absorbed
    • Children excrete less

• Inhalation
  – Higher absorption

• Biological Half-Lives and Deposition
  – Adults
    • Blood as PbB ~ 30 days
    • Bone ~ 10 or more years, some estimates as high as 30 years
  – Children may differ

Source: ACGIH TLV & BEI documentation, 2001
Distribution

• Skeleton is a significant sink for lead in the body
  – 97% lead burden in bone found post-mortem studies of lead workers
  – Studies show lead released from bone in times of bone loss, osteoporosis, pregnancy, breastfeeding, and workers with high cumulative chronic exposures with mean half-life of 6.7 years.

• Lead crosses placenta and accumulates in fetus

Source: ACGIH TLV & BEI documentation, 2001
Common Clinical Lab Tests

• Blood Lead measured by AA or ICP
  – indicative of recent exposure (within a month)

• Blood Erythrocyte Protoporphyrin (EP) or Zinc Protoporphyrin (ZPP)
  – indicative of fairly recent exposure (within several months)
  – not specific and not sensitive

• In vivo X-ray fluorescence of bone
  – indicates level of chronic exposures
OSHA Lead Standards

• General industry
  – 1910.1025
• Construction
  – 1926.62
• Widely accepted that inadequate protection at levels allowable in standards.
• Initial determination – General Industry
• Requirements triggered by air sampling results
  – Problem is air sampling misses incidental ingestion route of exposure
• Both standards specify frequency of air and blood sampling
• DOT contracts?
Lead Standards – Biological Testing

Frequency

General Industry Standard

• Required for all employees at or above airborne action level of 30 µg/m³ for more than 30 days per year

• Blood lead and ZPP levels
  – Every 6 months
  – Every 2 months for those above 40 µg/dL until 2 consecutive samples below 40 µg/dL
  – Every month for those medically removed until falls below 40 µg/dL
    • Confirmation within 2 weeks of employee notification

• Medical removal
  – 1 sample > 60 µg/dL or avg of three >50 µg/dL until sample < 40 µg/dL

Construction Standard

• Required for all employees at or above airborne action level of 30 µg/m³ for more than 30 days in 12 consecutive months

• Blood lead and ZPP levels
  – Every 2 months for first 6 months of employment then every 6 months afterwards
  – Every month for those medically removed
    • Confirmation within 2 weeks of employee notification

• Medical removal
  – 1 sample >50 µg/dL until 2 samples < 40 µg/dL
ABLES Data Characteristics

• Passive surveillance system
  – Subject to significant reporting bias
  – Highly variable testing frequency

• Duplication of cases problematic
  – Often data summarized as number of tests not number of individuals
  – In New Jersey, there were some months where 18% of the reported case IDs were duplicates
    • E.g. – Joao Britto vs John Britto

• Multiple tests per person
  – Many individuals with only 1 test; especially since all BLLs began to be reported in June 2003, which includes many non-occupational tests
  – Many occupational cases have multiple measures
    • Non-standardized follow-up times and testing frequencies
    • Non-uniform number of tests
    • Lost to follow-up
Methodology – Data Cleaning

• Utilized NJ ABLES database from 1985 – 2007
  ▪ 53,322 study ID’s existed in database
  ▪ 99,858 BLL tests existed in database

• Procedure developed to deduplicate the CASE ID numbers
  ▪ Utilized SAS “spedis” function, which utilized criteria to probability match
    ▪ Multiple iterations
    ▪ Cycle 1 involved grouping by last name while Cycle 2 involved grouping last names with identical names found in the first name field (to catch mistakenly transposed last and first name errors)
    ▪ Criteria for match based on “distance” calculated by Spedis function
      ▪ Records with identical last name, first name, and date of birth had distance of zero and were exact match and considered identical records. If these records had multiple ID’s they were corrected so they had only one ID.
      ▪ Records with distance > 0 then utilized a parsed date of birth (separated month, day, year) where one of the three parsed terms was allowed to not match because errors in month/day entry were common. Also address was utilized if necessary.
      ▪ Records with distance < 30 appeared to be matches by random manual checking of problem records. This was the distance criteria used for electronic probability matching.
      ▪ Manually checked random selection (1%) problem records after electronic matching
      ▪ Records that could not be resolved were left with separate IDs.

• Evaluated out of range values
  ▪ Excluded < 16 years of age or >89 years of age
Methodology – Data Cleaning (2)

• In the original 53,322 IDs
  ➢ 7.4% of them were corrected: Among them,
    ➢ 1,564 subjects were originally assigned to 2 reported IDs
    ➢ 181 subjects were originally assigned to 3 IDs
    ➢ 32 subjects were originally assigned to 4 IDs
    ➢ 18 subjects were originally assigned to 5 IDs
    ➢ 10 subjects were originally assigned to at least 6 IDs
  ➢ At the end, we identified 51,175 distinct subjects
    ➢ Only 6,355 (12%) of individuals had a SIC code.
      ➢ These people accounted for 41,134 tests (41%) in the database.
Occupational Group Comparisons

• Utilized NJ ABLES 2003 – 2007, where BLL Levels were reported within this time frame.
  • Data prior to 2003 was artificially truncated at 25 µg/dL

• Classified cases into two occupational categories for similar exposures based on SIC codes;
  – Manufacturing
    • Included SIC Codes; **Chemical Production & Pigments** (2821, 2851, 2816, 2819, 2865, 2869, 2891, 3089, 3087, 3083, 3081, 3082, 2899, 2892, 2893); **Storage Battery and Electronic NOS** (3691, 3679)
  – Construction and construction-like exposures
    • Included SIC codes; **General Construction including heavy** (1521, 1522, 1541, 1542, 1742, 1751, 1611, 1622, 1623, 1629, 1799, 1795, 1721, 1752, 1794); **Handling Scrap** (4953, 4959, 5093, 5051); and **Structural Steel** (1791, 1796)
Research Objectives and Statistical Methods

Research objectives: Use the NJ ABLES database to evaluate the difference between construction workers and manufacturing workers in
1) Length of intervals between adjacent BLL tests.
2) BLL trajectories.
3) Variability in BLL trajectories.

Statistical methods
1) Mixed model analysis for repeated measures was used for these comparisons.
2) Specifically, BLL trajectories, stratified by the “baseline” values, were modeled using natural splines with knots at every 60 days in the follow-up period (sensitivity analysis with knots at every 30 and 180 days in the follow-up showed similar result).
3) Baseline refers to the 1st test within the interval of 2003-2007.
10,609 tests on 1,577 people were identified for construction and manufacturing groups while our data analysis only included 1276 subjects with at least two tests after 2003.

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<th>overall</th>
<th>manufacturing</th>
<th>construction</th>
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<tbody>
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*Baseline is defined as the 1st test after 2003.
Distribution of the # of tests per subject in ABLES 2003 – 2007

overall

Manufacturing

Construction
Overall

The FREQ Procedure

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<tr>
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<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Frequency</th>
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<td>2</td>
<td>216</td>
<td>13.70</td>
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Manufacturing

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Construction:

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<th>Percent</th>
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<th>Cumulative Percent</th>
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<td>234</td>
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<td>26.26</td>
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<tr>
<td>2</td>
<td>160</td>
<td>17.96</td>
<td>394</td>
<td>44.22</td>
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<td>3</td>
<td>87</td>
<td>9.76</td>
<td>481</td>
<td>53.98</td>
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<td>4</td>
<td>74</td>
<td>8.31</td>
<td>555</td>
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<td>5</td>
<td>336</td>
<td>37.71</td>
<td>891</td>
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Manufacturing vs. Construction Workers with at Least 4 Repeated BLL Tests

Manufacturing Workers
(n=497)

Construction Workers
(n=410)
Time to follow-up testing

Mean length of time between adjacent tests

Average Length of Time between first test and second test (days)

Range of Initial BLL level (ug/dL)

- 0-5
- 5-11
- 11-20
- 20-25
- 25-80

Construction
Manufacturing
Comparisons of length between tests, stratified by baseline BLL values

<table>
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<th>Baseline BLL</th>
<th>Construction</th>
<th>Manufacturing</th>
<th>Difference</th>
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<tr>
<td>lower</td>
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<td>0</td>
<td>5</td>
<td>128.08</td>
<td>7.83</td>
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<tr>
<td>5</td>
<td>11</td>
<td>109.17</td>
<td>5.96</td>
</tr>
<tr>
<td>11</td>
<td>25</td>
<td>108.50</td>
<td>5.23</td>
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<tr>
<td>25</td>
<td>100</td>
<td>106.38</td>
<td>3.67</td>
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Trajectories for Manufacturing and Construction

Trajectory of Blood Lead Level for workers with baseline Blood Lead Level <= 5ug/dL

P-value=0.051
5ug/dL < Baseline Blood Lead Level <= 11ug/dL

P-value<0.0001
11ug/dL < Baseline Blood Lead Level <= 25ug/dL

P-value<0.0001
Baseline Blood Lead Level $\geq 25\mu g/dL$

P-value $< 0.0001$
Preliminary Observations

• Construction had significantly more variability than manufacturing in BLL values over time.

• Construction had significantly longer follow-up times for a second BLL test compared to manufacturing.

• Workers with higher baseline BLL may have more persistent BLL values, both in manufacturing and construction.

College students de-leading in Galveston Texas charity project [http://www2.gvsu.edu/richtelle/Disaster%20Relief-Galveston,%20TX.html](http://www2.gvsu.edu/richtelle/Disaster%20Relief-Galveston,%20TX.html)
Preliminary Interpretation

• Variability in exposures results in variability in biological makers of exposure, occupations with highly variable exposure need more frequent testing to properly characterize their risk.

• Trajectory of multiple BLL tests may be an indicator of BLL persistence.
Limitations & Further Analysis

• Limitations:
  – Incomplete data cleaning
  – Lost to follow-up
  – Truncation of data
  – Incomplete testing

• Additional analysis and modeling will be utilized to better understand this longitudinal data.

• Covariance will be accounted for in future models.
Thank you for your time!

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• Contact Information:

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