The Societal and Economic Costs of Cognitive and Behavioral Impairments due to Developmental Neurotoxicity Across the Lifespan

The Case of Lead

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Prelude
Dr. Leila Denmark
(1898-2012)

“...when you love what you do, it's not work, it is play.”
Dr. Leila Denmark, Atlanta Journal-Constitution.
Prelude
Dr. Herbert L. Needleman

Herbert L. Needleman, M.D.

‘Sometimes the data speak clearly’

Personal communication and many scientific press interviews and talks.
Decline in Blood Lead Levels in the United States

NHANES II AND NHANES III

Adapted from Needham, L. (2002)
Old, deteriorating and peeling paint is a continual source of lead in our inner-cities.
Age of Maximum Ingestion of Environmental Lead
The Age of Maximum Lead Ingestion and Early Cerebral Development

From Nolte (1993). The Human Brain
Expert Quantitative and Theoretical Assessments of the Societal and Economic Costs of Lead Exposure

• Estimated Costs in Terms of Intelligence as Measured by Lowered Full-Scale IQ


• Economic Impacts of Lead Exposure as Measured by Health Care, Special Education, Lower Earnings, and Crime

The Cincinnati Lead Study (1979 – 2016)
Fig 1. Blood lead concentrations obtained quarterly for children divided into four quartiles (Q1–4) based on average lifetime blood lead concentration (i.e., the mean of 20 quarterly blood lead concentrations from 3 to 60 months). Age in months has been abbreviated to 6-month intervals rather than 3-month intervals for clarity of presentation.

Early Exposure to Lead and Child IQ

Low-Level Environmental Lead Exposure and Children’s Intellectual Function: An International Pooled Analysis

Bruce P. Lanphear,1,2 Richard Hornung,1,2,3 Jane Khoury,1,2 Kimberly Yolton,1 Peter Baghurst,4 David C. Bellinger,5 Richard L. Canfield,6 Kim N. Dietrich,1,2 Robert Bornschein,2 Tom Greene,7 Stephen J. Rothenberg,8,9 Herbert L. Needleman,10 Lourdes Schnaas,11 Gail Wasserman,12 Joseph Graziano,13 and Russell Roberts14

N = 1,333

Source: Environ Health Perspect © 2005 National Institute of Environmental Health Sciences
Beyond IQ
Association of Blood Lead Levels and Self-Reported Delinquency in 16 Year-Old Adolescents in the Cincinnati Lead Study


Blood Lead Level

- Prenatal PbB
- Average Childhood PbB
- 78 Month PbB

Total Score

Lowest | Low | Medium | High
Questions from a Lead Study Cohort

- Why can’t I hold onto a job?
- Why can’t I get along with my girlfriend/wife?
- Why am I angry all of the time?
- Why can’t I concentrate?
- Why can’t my son/daughter stay out of trouble?
Blood Lead Concentration Profile of a 26 Year-Old CLS Male Subject with a History of Domestic Violence and Delinquent/Criminal Behavior
Blood Lead Concentration Profile of a 26 Year-Old CLS Male Subject with a History of Adult Criminal Behavior and Repeated Incarcerations

![Graph showing blood lead concentration profile over age in months.]
Does Early Exposure to Pb Leave a Long-Term Signature in the Brains and Behavior of Adults?

The Cincinnati Lead Study (1979-2016)

- Neuroimaging studies
- Criminality studies
Early Exposure to Lead and Adult Criminality
Environmental Factors in Criminal Disposition

- Parental dysfunction
- Community violence
- Poverty
- Media
- Lead
- Nutrition
- Alcohol
- Illicit Drugs

Cincinnati, 1956
Covariates in Analyses of Adult Criminality Data

- Home Environment (HOME score)
- Birth Weight
- Gender
- Age
- Maternal Smoking During Pregnancy
- Maternal Drug/ETOH Use During Pregnancy
- Maternal Education
- Maternal IQ
- Total Prior Maternal Arrests
- Socioeconomic Status
- Household Size
- Public Assistance
Average Number of Criminal Arrests in the Cincinnati Lead Study Cohort (M Age = 22 years) by Average Blood Lead Concentration and Gender (Unadjusted)

Wright, Dietrich, Ris et al. 2008

N = 250

Childhood Average Blood Lead Level ug/dL
Blood Lead Concentrations to Six Years and Arrest Rate Ratio for Violent Offenses*

*Any 5 ug/dL elevation in blood lead increased the rate of arrests for violent offenses by 48 percent.

Wright, Dietrich, Ris et al. 2008
Early Exposure to Lead and Career Criminality
Imaging Studies of the Cincinnati Lead Study Cohort (MRI, MRS, fMRI, DTI)
Covariates in Analyses of CLS
Adult MRI Data

- Home Environment (HOME score)
- Birth Weight
- Gender
- Maternal Smoking During Pregnancy
- Maternal Drug/ETOH Use During Pregnancy
- Maternal Education
- Maternal IQ
- Socioeconomic Status
- Household Size
- Public Assistance
- Age at time of imaging
- Positive drug screen
Cincinnati Neuroradiological Studies of Childhood Lead Exposure and Adult Brain Outcomes

- fMRI – dose-dependent reductions in brain activation in the traditional language areas (Yuan et al. 2006).

- HR Anatomical MRI – dose-dependent reductions in cortical gray matter in the frontal lobe (Cecil et al. 2008).

- DT MRI – dose dependent injury to both myelin and axonal structures (Brubaker et al. 2008).

- Proton MRS – dose-dependent reduction in gray matter NAA along with white matter choline declines (Cecil et al. 2011).
Verb Generation Task by Average Childhood Lead Exposure in the Cincinnati Lead Study

Low Average Mean Blood Lead (7.6 µg/dL)

High Average Mean Blood Lead (26 µg/dL)

Adult Cortical Gray Matter Loss in Cincinnati Lead Study Subjects in Relationship to Postnatal Lead Exposure to Six Years

International Implications
Fatal and Severely Disabling Infant and Childhood Lead Poisoning in Zamfara State Nigeria from Artisanal Gold Mining

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