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The intersection of aggregate-level lead exposure and crime

Brian B. Boutwell [a,b,*], Erik J. Nelson [b], Brett Emo [c], Michael G. Vaughn [a], Mario Schootman [b], Richard Rosenfeld [d], Roger Lewis [c]

[a] School of Social Work, College for Public Health & Social Justice, Saint Louis University, 3550 Lindell Boulevard, St. Louis, MO 63103-1021, United States
[b] Department of Epidemiology, College for Public Health & Social Justice, Saint Louis University, 3545 Lafayette Avenue, St. Louis, MO 63104-1399, United States
[c] Department of Environmental and Occupational Health, College for Public Health & Social Justice, Saint Louis University, 3545 Lafayette Avenue, St. Louis, MO 63104-1399, United States
[d] Department of Criminology and Criminal Justice, University of Missouri-St. Louis, One University Blvd., St. Louis, MO 63121, United States

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ABSTRACT

Context: Childhood lead exposure has been associated with criminal behavior later in life. The current study aimed to analyze the association between elevated blood lead levels (n=59,645) and crime occurrence (n=90,433) across census tracts within St. Louis, Missouri.
Design: Longitudinal ecological study.
Setting: Saint Louis, Missouri.
Exposure measure: Blood lead levels.
Main outcome measure: Violent, Non-violent, and total crime at the census tract level.
Results: Spatial statistical models were used to account for the spatial autocorrelation of the data. Greater lead exposure at the census-tract level was associated with increased violent, non-violent, and total crime. In addition, we examined whether non-additive effects existed in the data by testing for an interaction between lead exposure and concentrated disadvantage. Some evidence of a negative interaction emerged, however, it failed to reach traditional levels of statistical significance (supplementary models, however, revealed a similar negative interaction that was significant).
Conclusions: More precise measurements of lead exposure in the aggregate, produced additional evidence that lead is a potent predictor of criminal outcomes.

1. Introduction

There is no shortage of empirical research linking early life lead exposure with impaired functioning across a range of important developmental domains (Mahaffey et al., 1982; Needleman and Leviton, 1979; Needleman et al., 1990; Pocock et al., 1994; Hall 2013; Fergusson et al., 1988). Of particular relevance for the current study, however, is the body of research suggesting that lead exposure has been associated with an array of antisocial, and even criminal, behaviors later on in the life course (Hall, 2013; Fergusson et al., 1988). Along these lines, Wright et al. (2008) uncovered evidence suggesting that prenatal (and childhood) blood lead concentrations predicted arrests during adulthood in a cohort of over 200 subjects contained in the Cincinnati Lead Study. This finding aligns closely with other studies conducted by Needleman et al. (1996, 2002), Nevin (2007, 2000), and Dietrich et al. (2001) (who also analyzed Cincinnati Lead Study data from previous years) all examining the association between childhood lead exposure and negative outcomes such as violence and aggression. In short, there appears to be a confluence of evidence pointing towards an association between lead exposure and negative behavioral outcomes.

As a result of these intersecting streams of evidence, the United States Centers for Disease Control and Prevention (CDC) declared (years ago) that no amount of lead exposure in young children could be considered "safe." The CDC accordingly reduced the level of concern and action, measured by blood lead analysis, from 10 to 5 μg/dL (Canfield et al., 2003; Lanphear et al., 2000). Using the City of St. Louis as a case study, a variety of strategies aimed generally at removal of environmental sources of lead have been effective at reducing the number of children with blood-lead concentrations greater than the action level established by the CDC. When the action level was first set to 10 μg/dL in 1992, 48.5% of St. Louis

* Corresponding author at: School of Social Work, College for Public Health & Social Justice, Saint Louis University, 3550 Lindell Boulevard, St. Louis, MO 63103-1021, United States.
E-mail address: boutwellb@slu.edu (B.B. Boutwell).

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children screened were above the standard. In 2011, this was reduced to 12.4% using the more stringent lead action level of 5 μg/dL (City of St. Louis, 2012). Specific areas of the city, however, contain an aging housing stock which is important because aging homes represent an ongoing risk of lead exposure to child occupants (Kaufmann et al., 2000; Jones et al., 2009), and positive tests continue to emerge. In comparison with other U.S. cities, children in St. Louis experience an increased risk for lead poisoning due, in part, to the age of some of these properties (see http://scorecard.goodguide.com/env-releases/lead/, for rankings of St. Louis City relative to other cities provided by the joint project of Alliance for Healthy homes and Environmental Defense Fund, June 2011).

Despite an apparent link between lead exposure and violence at the individual level, it remains less certain whether aggregate lead exposure exerts a significant influence on macro-level outcomes such as aggregate crime (Stretesky and Lynch, 2001). This remains a critical empirical issue to examine, though, as identifying a significant association (or failing to identify one) may help to clarify neighborhood-based public-health strategies that could also be effective crime reduction tools (Stretesky and Lynch, 2004). Using air-lead concentrations across U.S. counties, Stretesky and Lynch (2001) provided one of the first clues regarding the effect of airborne lead concentrations on macro-level homicide (see also Stretesky and Lynch (2004)). More recently, Mielke and Zahran (2012) observed an association between airborne lead concentrations and aggravated assaults across six U.S. cities.

Though critically important, the aforementioned results raise several methodological issues in need of further scrutiny. First, a number of these studies relied on airborne lead levels to assess individual lead exposure in a given area (Stretesky and Lynch, 2001, 2004). The preferable approach would be to base exposure estimates on the actual lead burden of individuals residing in those areas rather than inferring population exposure from airborne lead measurements. Assessment of lead exposure using airborne estimates likely suffers from added measurement error as exposure estimates hinge largely on proximity to the air quality monitor and the concentration of airborne lead in a given area (Reyes, 2007).

Second, previous analyses have generally relied on data collected at the county (Stretesky and Lynch, 2001, 2004) or city level (Mielke and Zahran, 2012) (though see Lersch and Hart (2014)) within the United States, which may mask a considerable amount of variability between smaller geographic units, making it difficult to geographically target interventions. Third, while lead from air emissions has declined markedly due to the phase out of leaded gasoline and restrictions on airborne emissions in lead processing (Reyes, 2007), no previous study (to which we are aware) has established a relationship between lead hazards likely to originate from ageing housing stock and criminal behavior. Thus, there remains a need to examine whether lead levels can further predict variation of crime across lower levels of aggregation (e.g., census tracts within a given city).

Finally, previous research has relied largely on modeling approaches incapable of fully accounting for spatial autocorrelations that exist between lead exposure and societal adversity (e.g., crime, along with possible confounders such as poverty, race, and socioeconomic status). This is important in that failure to account for the spatial overlap in these variables may lead to an overstated (or incorrect) conclusion regarding the influence of lead on crime. The current study will overcome the limitations of previous investigations using individual blood lead measurements (aggregated to higher levels of measurement) and spatial statistics to account for spatial autocorrelation in order to further clarify the link between aggregate lead exposure and crimes (both violent and non-violent).

2. Methods

2.1. Aggregate blood lead levels

Census tracts have several appealing qualities underpinning their selection as the unit of aggregation. First, sufficient variation existed across census tracts (for all of the variables) for examining the covariation between lead and crime. In addition, the boundaries of census tracts remained constant across the years of the data. With this in mind, we geocoded the home addresses for 59,645 children less than 72 months in age who had blood lead level tests performed in St. Louis City from 1996 to 2007 as provided by the Missouri DHSS' Health Strategic Architecture and Information Cooperative (MOHSAIC) (see also Nelson et al., 2015) using ArcGIS version 10.2.2 (ESRI, Redlands, CA).[1] Blood samples from children in the City of St. Louis were collected, analyzed, and reported to the Missouri Department of Health and Senior Services over a period spanning 1996 to 2007. Specimen collection was conducted as part of normal regional lead screening activity. Population screening was not random and rates varied by year (in 2007 44.2% of children within the City were screened) (City of St. Louis, 2015). To further probe the nature of our lead measure we also tested the stability of blood lead exposure across individual years for each census tract. What the results suggested was that the number of individuals tested, as well as the proportion of individuals testing positive for elevated BLLs, remained relatively constant across time. As a result, aggregating blood lead exposure from 1996 to 2007 seemed to provide a reasonable approximation for the ambient presence of lead at that time, while also offering an appropriate time lag between exposure and crime.

Blood lead values were assigned to the primary listed residence of the children from which tests were derived and the highest recorded blood lead level was used to represent that residence. Results for capillary lead testing were accepted only in the absence of venous testing for a given residence. The lead test results associated with 59,645 residences were then aggregated to the census tract level. The number of blood lead level tests with ≥ 5 mg/dL (a standard approach in individual-level research (Wright et al., 2008)) were then aggregated to census tracts within St. Louis City ($n=106$) resulting in a mean number of 562.3 ($SD=368.4$; $Min=17$; $Max=1581$) blood lead level tests within each census tract. The number of elevated tests were then divided by the total number of blood lead level tests to estimate the proportion of high blood lead level within each census tract ($mean=0.43$; $SD=0.17$; $Min=0.07$; $Max=0.74$).

2.2. Aggregate level crime

In order to assess crime incidences throughout the city, we geocoded 90,433 locations where crimes had occurred (across all ages) (95% of all crimes) in St. Louis City as reported in the Federal Bureau of Investigations' Unified Crime Report across the years 2010–2012 (all crime data were provided by the St. Louis Metropolitan Police Department) (Nelson et al., 2015; Federal Bureau of Investigation. Uniform Crime Reports, 2014). Crime occurrences were deemed as either violent ($n=15,734$) or non-violent ($n=74,699$) based on the FBI crime classification system. After aggregating the data, the results yielded on average 148.4 ($SD=101.1$; $Min=4$; $Max=457$) acts of violent crime, 704.6 ($SD=405.7$; $Min=131$; $Max=3271$) acts of non-violent crime and 853.0 total criminal acts ($SD=482.5$; $Min=147$; $Max=3728$), per census tract (for the years 2010-2012).

[1] Saint Louis University Institutional Review Board (IRB) approved access to the data, however, the researchers involved in the current study did not collect or handle the data, nor did we have access to the original respondent's identifying information.