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Childhood lead exposure and sexually transmitted infections: New evidence

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A B S T R A C T

Introduction: The adverse health effects of lead exposure in children are well documented and include intellectual and behavioral maladies. Childhood lead exposure has also been linked to impulsive behaviors, which, in turn, are associated with a host of negative health outcomes including an increased risk for sexually transmitted infections (STI). The purpose of this study was to assess the association of lead exposure with STI rates across census tracts in St. Louis City, Missouri.
Methods: Incident cases of gonorrhea and chlamydia (GC) during 2011 were identified from the Missouri Department of Health and Senior Services and aggregated by census tract. We also geocoded the home address of 59,645 children >72 months in age who had blood lead level tests performed in St. Louis City from 1996 to 2007. Traditional regression and Bayesian spatial models were used to determine the relationship between GC and lead exposure while accounting for confounders (condom and alcohol availability, crime, and an index of concentrated disadvantage).
Results: Incident GC rates were found to cluster across census tracts (Moran's $I=0.13$, $p=0.006$). After accounting for confounders and their spatial dependence, a linear relationship existed between lead exposure and GC incidence across census tracts, with higher GC rates occurring in the northern part of St. Louis City
Conclusions: At the census-tract level, higher lead exposure is associated with higher STI rates. Visualizing these patterns through maps may help deliver targeted interventions to reduce geographic disparities in GC rates.

1. Introduction

The adverse health effects of lead exposure in children have been well documented and include intellectual and behavioral maladies (Agency for Toxic Substances and Disease Registry, 2007). Reyes demonstrated that lead in gasoline in the U.S., as it was being phased out (circa 1980), was related to early sexual activity, teenage pregnancy and substance use (Reyes, 2014). Although lead in gasoline has been reduced by 99% (United States Environmental Protection Agency, 1998), old housing stock (primarily lead based paint and dust containing lead particles) remains a persistent source of lead exposure though nationwide remediation efforts have made gains in reducing this source of exposure in many parts of the U.S. (Malone, 2014).

In the wake of rapidly accumulating research regarding the negative influence of lead and despite the success in reducing lead exposure among children in the U.S., the Centers for Disease Control and Prevention (CDC) declared that there is no safe blood lead level (BLL) in children (Centers for Disease Control and Prevention, 2013) and subsequently reduced the level for lead intervention from 10 μg/dL (microgram of lead per deciliter of blood) in 1991 to 5 μg/dL in 2012 (Lanphear et al., 2000; Canfield et al., 2003). Missouri is the leading producer of lead ore and lead byproducts in the United States and has multiple locations on the U. S. Environmental Protection Agency's National Priorities List for lead hazards (Missouri Department of Health and Senior Services, 2015). St. Louis City has a long history of lead remediation

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programs and has been able to reduce the percentage of children who test positive for elevated BLLs (City of St. Louis Department of Health, 2012). For example, nearly 50% of St. Louis children screened in 1992 were above the then 10 μg/dL standard, whereas only 12.4% of children were above the more stringent lead standard of 5 μg/dL in 2011 (City of St. Louis Department of Health, 2012). However, many areas remain throughout St. Louis City where old housing units continue to expose children to lead, as evidenced by continued elevated BLL tests among children, which are the highest in the state (Kaufmann et al., 2000; Missouri Department of Health and Senior Services, 2015).

Childhood lead exposure has also been linked to impulsive behaviors (Needleman et al., 1990, Needleman et al., 2002; Wardell et al., 2015), which, in turn, are associated with alcohol use and addiction, as well as violence and aggression (Sher and Trull, 1994; Littlefield et al., 2010). Impulsive personality traits are also hypothesized to impair control processes and may increase an individual's propensity towards risk (Leeman et al., 2012). Studies have shown that impulsivity is, in turn, associated with a host of negative health outcomes including an increased risk for both contracting, and exposing others to, sexually transmitted infections (STI) (O'Leary et al., 2005; Mehrotra et al., 2009; Moffitt et al., 2011; Leeman et al., 2012; Wardell et al., 2015). Put differently, sexual compulsivity has been implicated as a predictor of STI risk (Dodge et al., 2004; Gullette and Lyons, 2005; Semple et al., 2006). If lead exposure is indeed causally associated with sexual compulsivity, then remediating the effects of lead may serve to prevent STIs.

There are several factors that increase risk for exposure to STIs. STIs disproportionately burden adolescent and young adult women (Lazzarin et al., 1991); findings that are not necessarily surprising given that the regions of the brain implicated in decision making and executive function (i.e., self-control) are still in development at this stage of the life course. Known risk factors for unprotected sex, which greatly increase the potential for STI infection (and are likely correlated with impulsivity), include age (Burk et al., 1996), heavy alcohol and illicit drug use (Stall, 1994; Sikkema et al., 1996; Compton et al., 1998; Cottler et al., 1998; Coyle, 1998; Bogart et al., 2005; Sikkema, 2005; Buffardi et al., 2008), and psychological distress (all of which are also correlates of diminished impulse control) (Morrill et al., 2001; Shrier et al., 2001; Kathryn et al., 2006). As noted by Cooper et al., several ecologic and multi-level studies have proposed that STI prevalence is also positively associated with poverty, social disorder and racial segregation (Du et al., 2009; Kaplan et al., 2009; Cooper et al., 2014) – all of which cluster in certain geographic areas (Wright et al., 2014). Neighborhood environment may shape an individuals' access to local resources such as healthcare, condom availability, employment, education and safety (Jennings, 2014; Shacham et al., 2015). What this necessarily means is that there are a variety of reasons why lead exposure and STI risk might covary, however, these pathways are complex and subject to confounding. Even so, understanding potential connections between lead exposure and health outcomes within the context of neighborhoods may further elucidate the sequelae of lead exposure.

The first step towards understanding the connection between lead exposure and STI rates within neighborhood contexts is to examine these relationships using an ecological framework. Using data from the Missouri Department of Health and Senior Services (DHSS) on childhood lead exposure and STI rates, the purpose of this study was to assess the association of lead exposure with STI rates across census tracts in St. Louis City, Missouri. We hypothesized that increased lead exposure (i.e., higher proportions of elevated BLL tests) was associated with higher rates of gonorrhea and chlamydia.

2. Methods

2.1. Study design

An ecologic study design was used to assess the aggregate association between lead exposure and incident STIs across all 106 census tracts in St. Louis City. Based on the literature (Bogart et al., 2005; Buffardi et al., 2008; Shacham et al., 2015), factors such as condom and alcohol availability, crime, and poverty were identified as known confounders and included in the analyses. These measures are described in detail below. The Institutional Review Board at Saint Louis University approved this study.

2.2. Data

2.2.1. Gonorrhea and chlamydia incidence rates

Census tracts were selected as the unit of aggregation because they provide sufficient variation across geographic areas while also having data available for area-level characteristics. As required by law, incident cases of gonorrhea and chlamydia (GC) during 2011 were reported to the Missouri DHSS and subsequently geocoded to census tracts. Of the 13,735 GC cases that occurred in St. Louis City, 974 (7.1%) were not able to be geocoded to the census tract and could not be included in the analysis. We calculated crude rates of incident GC for each census tract based on the remaining data. We also used indirect standardization to calculate the standardized morbidity ratio (SMR) for each census tract (Rothman et al., 2008), which represents the observed GC rate relative to the expected GC rate.

2.2.2. Blood lead levels

We also obtained the home address of 59,645 children less than 72 months in age who had BLL tests performed in St. Louis City from 1996 to 2007 from the Missouri DHSS' Health Strategic Architecture and Information Cooperative (MOHSAIC) and geocoded those to the census tract using ArcGIS version 10.2.2 (ESRI, Redlands, CA). We aggregated all BLL tests to census tracts within St. Louis City, resulting in a mean of 562.3 (SD=368.4; Min=17; Max=1581) BLL tests per census tract. We then calculated the proportion of BLL tests with ≥5 mg/dL (a standard approach in individual-level research (Wright et al., 2008)) within each census tract. The average proportion of high BLL (i.e., ≥5 mg/dL) within each census tract was 0.43 (SD=0.1; Min=0.07; Max=0.74).

2.2.3. Aggregate level crime

We geocoded the locations of 90,433 occurrences of crime regardless of the victim's ages in St. Louis City as reported in the Federal Bureau of Investigations' Unified Crime Report for the years 2010–2012 (Federal Bureau of Investigation, 2014). After aggregating the data, there were an average of 853.0 total criminal acts 20.11 per 1000 people (SD=482.5; Min=147; Max=3728) per census tract. The mean crime rate across census tracts was 20.11 per 1000 people (SD=14.44; Min=0.78; Max=54.05).

2.2.4. Condom vendors and alcohol outlets

We geocoded the location of businesses (n=233) and other places (n=47) where condoms are sold and/or distributed within St. Louis City, which were identified previously through a comprehensive business audit in 2012 (Shacham et al., 2015). We also geocoded the location of all licensed alcohol outlets in St. Louis City during 2008 (State of Missouri Data Portal, 2008). In order to capture condom and alcohol availability based on geographic location, we computed the number of condom vendors, as well as the number of alcohol outlets within buffers of each census tract. We computed the number of condom and alcohol outlets within buffers of 0.1, 0.25, 0.5 and 1.0 mile radii. We ultimately chose the