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The conjoint influence of home enriched environment and lead exposure on children's cognition and behaviour in a Mexican lead smelter community

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ABSTRACT

A range of studies has been conducted on the detrimental effects of lead in mining and smelting communities. The neurocognitive and behavioural health effects of lead on children are well known. This research characterized the conjoint influence of lead exposure and home enriched environment on neurocognitive function and behaviour for first-grade children living in a Mexican lead smelter community.

Structural equation models were used for this analysis with latent outcome variables, Cognition and Behaviour, constructed based on a battery of assessments administered to the first-grade children, their parents, and teachers. Structural equation modelling was used to describe complex relationships of exposure and health outcomes in a manner that permitted partition of both direct and indirect effects of the factors being measured.

Home Environment (a latent variable constructed from information on mother's education and support of school work and extracurricular activities), and child blood lead concentration each had a main significant effect on cognition and behaviour. However, there were no statistically significant moderation relationships between lead and Home Environment on these latent outcomes. Home Environment had a significant indirect mediation effect between lead and both Cognition and Behaviour (p-value < 0.001). The mediation model had a good fit with Root Mean Square Error of Approximation <0.0001 and a Weighted Root Mean Square Residual of 0.895. These results were highly significant and suggest that Home Environment has a moderate mediation effect with respect to lead effects on Behaviour ($\beta = 0.305$) and a lower mediation effect on Cognition ($\beta = 0.184$). The extent of home enrichment in this study was most highly related to the mother's support of schoolwork and slightly less by the mother's support of extracurricular activities or mother's education. Further research may be able to develop approaches to support families to make changes within their home and child rearing practices, or advocate for different approaches to support their child's behaviour to reduce the impact of lead exposure on children's cognitive and behavioural outcomes.

1. Introduction

A range of studies has been conducted on the health effects of lead in mining and smelting communities (Baghurst et al., 1992, 1999; Boreland et al., 2008; Boreland and Lyle, 2009; Burns et al., 1999; Kardamanidis et al., 2008; Kordas et al., 2006, 2007; Landrigan et al., 1976; Landrigan, 1996; McMichael et al., 1994; Sawyer et al., 1996; Tong et al., 1998). It is well known that lead exposure negatively affects child neurocognitive and behavioural function in children from these communities and from exposures to other sources (Bellinger, 2008; Braun et al., 2006, 2008; Dietrich et al., 2001; Lanphear et al., 2005a,b; Needham et al., 2005). Recent studies show that neurobehavioural deficits can be discerned at blood lead concentrations well below the Center for Disease Control and Prevention's (CDC) guideline of 10 μg/dL (Bellinger,

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2008; Braun et al., 2006, 2008; Dietrich et al., 2001; Lanphear et al., 2005a,b; Needham et al., 2005). Additionally, some studies have identified associations of early life lead exposure with future adolescent pregnancy, delinquency and criminal arrest rates (Dietrich et al., 2001; Needleman et al., 2002; Nevin, 2000, 2007; Wright et al., 2008).

In lead contaminated communities, screening of blood lead levels is an important means to identify children at risk, and to apply early interventions, such as mitigation of exposure sources and provision of education and resources to reduce long-term deficits (Center for Disease Control and Prevention, 2005; Valent et al., 2004). Environmental control is an appropriate response to protect child health from further lead exposure, however, it does not address individual health effects already incurred. Alternative interventions aimed at child development may be effective, though this has not been well studied in relation to the neurocognitive and behavioural effects of lead.

In child development literature, enriched environments have been demonstrated to stimulate children's learning (Duderstadt, 2006; High & American Academy of Pediatrics Committee on Early Childhood, Adoption, and Dependent Care and Council on School Health, 2008; Zuckerman and Halfon, 2003). Early childhood stimulation enhances child development and can counteract some of the effects previously thought to be irrevocable, such as antisocial behaviour and cognitive deficits of stunted children (Walker et al., 2005). It is plausible that the neurocognitive effects associated with lead exposure may be partially ameliorated by the provision of enriched environments for the affected children. Animal studies show some promise in this regard (Guilarte et al., 2003). These results demonstrate potential for implementing intervention strategies if an enriched environment can be shown to positively influence the development and learning of children exposed to lead. The extent to which the social effects of lead exposure may contribute negatively to familial relationships and participation in the home environment is not well known.

The goal of this analysis was to characterize the conjoint influence of lead exposure and home enriched environment on neurocognitive function and behaviour for first-grade children living in a lead smelter community in Torreón, México. The presence of an enriched home environment has been shown to improve child development challenges in many contexts (Barker and Maughan, 2009; Combs-Ronto et al., 2009; Kerr et al., 2004; Ladd and Burgess, 2001; Walker et al., 2005). In this analysis we examined whether the negative cognitive and behavioural health effects associated with life lead exposure could be affected by the quality of the home environment, measured as the combined effects of a number of maternal influences within the child's home.

2. Methods

A secondary data analysis is presented of the original 2001 study conducted in Torreón, México by researchers from the Johns Hopkins Bloomberg School of Public Health in Baltimore, MD, the Institute of Medical Sciences and Nutrition and the University of Juarez in Durango, México. This current research was analyzed with the additional participation of Cornell University in Ithaca, NY, and the University of Queretaro in México.

The original analysis of the 2001 cohort of first-grade children reported that their concurrent blood lead concentration (mean 11.4 μg/dL, SD 6.1 μg/dL) was inversely associated with a variety of cognitive and behavioural test scores (Kordas et al., 2004). This paper reports on a reanalysis of the data, using structural equation models, to provide new evidence on the potential mediation effects of the home environment on behaviour and cognition of the lead exposed children.

2.1. Study location

The study location was Torreón, Mexico, a community with a lead smelter surrounded by residential areas. Torreón and the neighbouring cities of Gómez Palacio and Lerdo, in the Región Lagunera of central Mexico have a total population of around 900,000 inhabitants.

The Met-Mex Peñoles lead smelter in Torreón has been in production since 1901 (Met-Mex Peñoles, 2009). This smelter is the largest active nonferrous smelting complex in Latin America and fourth largest in the world (Met-Mex Peñoles, 2009; International Lead Development Association, 2009). There is a large slag heap of smelter waste products next to the smelter that is exposed to wind erosion. Since the weather is semi-arid, dry and dusty with an annual rainfall less than 20 inches, blowing dust from this waste was a high source for metal exposure (Calderon-Salinas et al., 1996a,b). Deposition of metals to the environment and soils around the smelter was highest near the smelter with the prevailing wind direction (Albalak et al., 2003; Benin et al., 1999; Calderon-Salinas et al., 1996a,b; Garcia Vargas et al., 2001b). To date, lead concentrations of soil and outdoor dust continue to be orders of magnitude above background (ranging 130–12,050 μg/g for soil and 150–14,365 μg/g for dust) (Soto-Jimenez and Flegal, 2011). In 2001, several residential areas were within 5 kilometres to the smelter, which exposes children and adults to dust blown from the waste and other smelter-related sources of lead (Calderon-Salinas et al., 1996a,b; García Vargas et al., 2001a).

2.2. Study population

The study population and participant recruitment process is described elsewhere (Kordas et al., 2006). Children eligible for the original study were in first grade during January 2001 and attending one of 9 schools within 3.2 kilometres of the lead smelter in Torreón.

The 2001 study was approved by the committees on human research at the Johns Hopkins Bloomberg School of Public Health in Baltimore, MD, and the National Institute of Medical Sciences and Nutrition in México. Approval was also given by the Ministries of Education and Health in the state of Coahuila, where Torreón is located.

2.3. Data

The methods for the data collection of this research are presented elsewhere (Kordas et al., 2006). Standard procedures were followed for venous blood lead sampling and analysis using Atomic Absorption Spectrometry with graphite furnace atomization, corrected with Zeeman Effect (García Vargas et al., 2001a). All the home environment data were collected in 2001 from parent and teacher interviews and questionnaires (more detail is available in Kordas et al., 2006). A neurocognitive testing battery of 14 paper and pencil or computer based tasks was used to assess specific and global domains of cognition (see Table 1, Section 2.3). There were 10 Mexican psychologist evaluators who administered the tests.

2.4. Statistical analysis

This analysis was designed to evaluate the conjoint influence of lead exposure and the quality of the home environment on neurocognitive and behavioural outcomes for children exposed to lead. The analysis used children's blood lead concentrations and measures of the attributes of the home environment to predict cognitive and behavioural outcomes. The home environment variable as well as the outcome variables were constructed as latent class variables based on a factor analysis, as described below.