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Moderate lead exposure and elementary school end-of-grade examination performance

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ABSTRACT

Purpose: This study investigated the association between moderate lead poisoning in early childhood with performance on a comprehensive set of end-of-grade examinations at the elementary school level in two urban school districts.

Methods: Children born between 1996 and 2000 who resided in Milwaukee or Racine, WI, with a record of a blood lead test before the age of 3 years were considered for the analysis. Children were defined as exposed (blood lead level $\geq$10 and $<$20 μg/dL) or not exposed (BLL $<$ 5 μg/dL). Parents of eligible children were mailed surveys to consent to participation and elicit information on potential confounders. On consent, children were matched to educational records for fourth grade Wisconsin Knowledge and Concepts Examinations. Seemingly unrelated regression was used to evaluate the relation between scaled scores on all sections of the examination (math, reading, language arts, science, and social studies) with exposure status, controlling for demographics, social status indicators, health indicators, and district-based poverty indicators.

Results: A total of 1133 families responded to the survey and consented to have educational records released; 43% of children were considered exposed. After controlling for demographic and socioeconomic covariates, lead exposure was associated with significantly lower scores in all sections of the Wisconsin Knowledge and Concepts Examinations (range: science, $\beta = -5.21$, $P = .01$; reading, $\beta = -8.91$, $P = .003$). Children who were black, had a parent with less than a high-school education, and were classified by parents as having less than excellent health had significantly lower performance on all examination components.

Conclusions: Children with moderate lead poisoning in early childhood performed significantly lower on all components of elementary school end-of-grade examinations compared with unexposed children. Household level social status and childhood health indicators partially explain decreased examination scores.

Introduction

The ban on lead additives from gasoline and household paint in the United States has resulted in a dramatic decrease in childhood lead exposure [1–3]. Due to the durability and persistence of lead in the environment, children's exposure to lead continues. Various studies have demonstrated consistently that children who are black, in low-income families, and reside in older housing are at risk for elevated blood lead levels (eBLL) [4–6]. Although lead exposure is a public health concern in both urban and rural communities [7], the population density in urban communities and the absolute number of children exposed contribute to the conceptualization of lead exposure as a primary urban environmental health issue.

More than four decades ago, the cognitive effects of early life exposure to low doses of lead were established [8]. The

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preponderance of the data that link lead exposure to declines in cognitive performance has been established largely through intelligence quotient (IQ) testing [9–13]. Although informative from an etiologic perspective, the implications of cognitive deficits as measured by IQ testing may have limited relevance in contextual settings, particularly related to educational performance and outcomes [14]. Standardized testing, including statewide end-of-grade (EOG) examinations, may be an informative metric to measure the impact of early childhood lead exposure. Performance on these tests determines educational advancement and placement decisions for students and has implications for meeting federal No Child Left Behind standards [15]. Furthermore, performance on these examinations has been associated with life-course events that directly or indirectly impact health status such as future educational achievement [16], high-school dropout [17], delinquency [18], future employment and wages [19], and mortality [20]. Although myriad factors both intrinsic and extrinsic to the school environment have been associated with poor scholastic outcomes in urban school districts, recent studies have suggested that lead exposure may partially explain low performance on EOG testing in affected communities [21–25].

Studies that have investigated the relation between early childhood lead exposure and performance on EOG examinations have relied solely on administrative data. Large studies are possible through the use of data repositories from school districts; however, the lack of additional information on individual- and household-level covariates may result in unmeasured confounding and may bias current estimates of effects. Of particular concern are measures that reflect household structure, socioeconomic status (SES), comorbidities, ongoing exposure to lead, or additional environmental exposures associated with cognitive effects [26]. Some of these covariates may be available through administrative data, such as eligibility for the National School Lunch Program, but direct surveillance of families of children who were tested for lead in early childhood may provide more comprehensive information on covariates that mediate, moderate, or confound the effect of lead exposure on school performance. Furthermore, studies that collect comprehensive contextual information may elucidate mechanisms through which lead exposure may impact educational performance, may identify other indicators that distinguish subgroups at risk of lead exposure and low educational performance, and may indicate possible domains for improved interventions. Thus, the objective was to estimate the effect of moderate lead exposure in early childhood on EOG examinations taken at the elementary school level in two urban school districts.

Methods

Human subjects

The protocol for this study was approved by the University of Wisconsin-Madison Education Research Institutional Review Board. All parents or guardians signed informed consent forms before participation.

Study population

Milwaukee Public Schools (MPS) and the Racine Unified School District (RUSD) are the first and fourth largest school districts in Wisconsin, respectively, and have been identified as high-risk communities by the Wisconsin Childhood Lead Poisoning Prevention Program (WCLPPP) [27].

Academic performance

The Wisconsin Knowledge and Concepts Examination (WKCE) is a Wisconsin standardized examination administered to public school students in grades 3–8 and 10. Each grade is tested on mathematics and reading; in 4th, 8th, and 10th grade, students are also tested on language arts, social studies, and science. Beginning in 2002, the fourth grade WKCE became one factor in deciding whether individual students advance from fourth to fifth grade [28]. The fourth grade tests were selected for this study because they are the most comprehensive during the elementary grades. Students receive a raw score in each subject area, which is then converted to a scaled score intended to maintain a similar distribution of scores across multiple years.

Sample construction

To determine study eligibility, Wisconsin Department of Public Instruction (DPI) records of fourth grade EOG scores completed between 2005 and 2010 were merged with blood lead level (BLL) data maintained by the WCLPPP in the Wisconsin Department of Health Services. The target population consisted of children who met the following eligibility criteria: (1) born between January 1, 1996 and December 31, 2000; (2) BLL tested by capillary or venous test before their third birthday and results reported to WCLPPP; (3) Milwaukee or Racine address at the time of one or more blood lead tests; and (4) confirmed by DPI to have taken a fourth grade state assessment examination.

Blood lead levels

From 1991 to 2012, the Centers for Disease Control defined eBLL as 10 μg/dL or more. However, in a majority of state-level lead programs, interventions have only been available for children with BLL 20 μg/dL or more. The definition of the exposed group was designed to capture children considered to have eBLL, but at a level of "moderate exposure," below the level at which state law mandates remediation. Children were either "exposed" (children tested at least once before their third birthday with a result $\geq$10 and $<$20 μg/dL) or "not exposed" (children tested between 18 and 36 months of age with BLL $<$ 5 μg/dL). The Wisconsin State Laboratory of Hygiene established a limit of quantification of 5 μg/dL for all blood lead analysis before 2000; this standard was used to define the nonexposed group and anchor the low end of the quantifiable lead exposure spectrum. In addition, a child could only be classified as exposed if they never had a result 20 μg/dL or more in their lifetime. Similarly, a child classified as not exposed could not have a BLL result more than 5 μg/dL at any age. Although the Wisconsin State Laboratory of Hygiene has lowered their limit of quantification since 2000, the more stringent definition of nonexposure was used to coincide with the time of testing for the study population.

Recruitment

Contact information, consisting of current addresses and phone numbers, for the parents or guardians of eligible children could not be obtained from DPI or MPS because of internal data sharing restrictions. However, RUSD did provide addresses and phone numbers for children matched with their records. With the Superintendent of School's approval, a Memorandum of Understanding was established to obtain parent or guardian contact information and the current school attended for eligible children who were still attending an RUSD school. To obtain similar information for the Milwaukee children, study staff used the University of Wisconsin Survey Center to trace current addresses for eligible