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Lead exposure and educational proficiency: moderate lead exposure and educational proficiency on end-of-grade examinations

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ABSTRACT

Purpose: To investigate and quantify the impact of moderate lead exposure on students' ability to score at the "proficient" level on end-of-grade standardized tests.
Methods: We compared the scores of 3757 fourth grade students from Milwaukee, Wisconsin, on the Wisconsin Knowledge and Concepts Exam (WKCE). The sample consisted of children with a blood lead test before age 3 years that was either unquantifiable at the time of testing (<5 μg/dL) or in the range of moderate exposure (10–19 μg/dL).
Results: After controlling for gender, poverty, English language learner status, race/ethnicity, school disciplinary actions, and attendance percentage, results showed a significant negative effect of moderate lead exposure on academic achievement for all 5 subtests of the WKCE. Test score deficits owing to lead exposure were equal to 22% of the interval between student categorization at the "proficient" or "basic" levels in Reading, and 42% of the interval in Mathematics.
Conclusions: Children exposed to amounts of lead before age 3 years that are insufficient to trigger intervention under current policies in many states are nonetheless at a considerable educational disadvantage compared with their unexposed peers 7 to 8 years later. Exposed students are at greater risk of scoring below the proficient level, an outcome with serious negative consequences for both the student and the school.

Childhood lead exposure has been recognized as a major public health issue for over a century. Lead exposure is associated with a wide variety of negative health impacts [1], including protracted physical development and smaller stature [2,3], gastrointestinal disorders [4], lower cognitive function [5–7], antisocial behavior and delinquency [8–13], and in severe cases death [14]. The preponderance of studies demonstrate a consistent albeit modest effect of early childhood lead exposure on cognitive function, often measured by intelligence quotient (IQ) tests [15–19]. Partly because IQ test scores are a familiar measure with proven sensitivity, the association of early life lead exposure with IQ scores has been frequently used in risk analyses and for defining risk levels [1]. Although IQ scores are often statistically correlated with academic and professional success in life, until recently few studies have investigated the relationship of lead exposure with more direct educational outcomes such as end-of-grade examinations, which can deterministically influence students' academic trajectories.

School achievement tests have taken on increasing importance in the United States following federal policies that evaluate schools and teachers according to the performance of students on standardized tests administered by each state. The assignment of proficiency categories based on students' scores is emphasized. Schools are required to achieve target percentages of children performing at or above the "proficient" level in reading and math. Schools failing to meet benchmarks risk cuts to funding or closure, making these tests a high-stakes outcome for students, schools, and their communities. The extent to which lead exposure is negatively associated with performance on standardized tests has important implications for American educational policy, as well as public health.

The upper Midwest of the United States, which includes Wisconsin, has a relatively high risk of lead exposure. According to surveillance conducted by the Wisconsin Childhood Lead Poisoning Prevention Program (WCLPPP), in 2006 the statewide prevalence of lead exposure over the level of concern at the time (blood lead level [BLL] ≥10 μg/dL) was 2.6% for tested children under 2 years of age; more than twice the national prevalence. Approximately 5% of children who entered the Wisconsin public school system in 2006 had at least one test result above the level of concern [20]. Despite

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this high prevalence, state public health interventions in Wisconsin and many other states are currently mandated only for children with elevated BLL defined as 20 μg/dL or greater. There are neither state-mandated interventions nor secondary prevention efforts targeted to children with BLLs that are considered elevated but less than the 20 μg/dL threshold, although some municipalities and counties provide resources. In 2012, the Centers for Disease Control and Prevention (CDC) accepted the recommendation of the Advisory Committee on Childhood Lead Poisoning Prevention [21], and replaced the previous level of concern (10 μg/dL) with a new reference level calculated every 4 years as the 97.5th percentile of BLLs in in the two most recent National Health and Nutrition Examination Survey datasets. This change was made in response to an accumulation of evidence suggesting that there is no safe level of lead exposure [22], with the effect of increasing the number of children that the CDC considers at risk for negative consequences of lead exposure. The present study examines the educational impact of lead exposure, in terms of meeting or failing to meet the "proficient" level on an end-of-grade examination, for children with BLL test results that are elevated but below the threshold for mandated intervention (20 μg/dL).

Methods

We used WCLPPP data to select children from Milwaukee with a BLL test of 10 μg/dL or greater and less than 20 μg/dL before the age of 3. We compared these children having moderately elevated BLL with those with a blood lead test before age 3 but with BLL considered unquantifiable by the Wisconsin State Laboratory of Hygiene (WSLH) at the time of testing (<5 μg/dL). We examined data from children who resided in Milwaukee at the time of their blood test owing to sample size considerations: In addition to being the largest city in Wisconsin, Milwaukee has the highest prevalence of elevated BLLs in children (6.1%) of any municipality in the state [20]. The protocol for this study was approved by the University of Wisconsin—Madison Education Research Institutional Review Board.

Blood lead levels

In 2006, approximately 20% of Wisconsin children under 6 years of age had their blood lead levels tested. Many parents have their children tested voluntarily; however, Wisconsin mandates lead screening for children enrolled in Medicaid and Women, Infants, and Children at their 1st and 2nd birthdays. Sixty-seven percent of children tested in Wisconsin in 2006 were enrolled in one of those programs. Health care providers are required by Wisconsin Administrative Code (HFS 181) to report BLL results to WCLPPP, or to direct the analyzing laboratories to do so. Children in Wisconsin have their blood drawn in clinics, doctor's offices, and hospitals, and their samples are tested by a number of different laboratories. There is substantial variation in the limits of quantification established by individual laboratories. The WSLH, which analyzes more than one quarter of all samples, established a limit of quantification of 5 μg/dL for all blood lead analysis before 2000. Although many laboratories, including the WSLH, are currently able to reliably test below this level, we use it to anchor the low end of the quantifiable lead exposure spectrum in our study because more than half of the BLL results in our sample were tested during this period, many at the WSLH. Our definition of "not exposed" is based on the WSLH limits of quantification at the time of testing, which is also the current CDC reference level [22].

Academic performance

The Wisconsin Knowledge and Concepts Examination (WKCE) is a Wisconsin standardized examination administered to public school students in grades 3 through 8 and 10. Every grade is tested on Mathematics and Reading; in 4th, 8th, and 10th grade students are also tested on Language Arts, Social Studies, and Science. The 4th-grade WKCE is one factor in deciding whether individual students advance to 5th grade [23]. The 4th-grade examination was selected for study, because it is the most comprehensive and high-stakes exam given during the elementary years. Students receive a raw score in each subject area based on the number of questions answered correctly, which is converted to a scaled score intended to maintain a similar distribution of scores across multiple years. The scaled scores are the primary score of interest to Wisconsin educators and policymakers to determine whether schools are meeting federal standards; for that reason, we conducted our analyses using the scaled scores.

Study sample construction

Our sample was constructed by combining Milwaukee Public Schools (MPS) records of academic performance with BLL data maintained by WCLPPP. The sample 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 3rd birthday and results reported to WCLPPP; (3) Milwaukee address at the time of one or more blood lead tests; and (4) confirmed by the Wisconsin Department of Public Instruction to have taken the 4th-grade WKCE. Children were defined as either "exposed" (children tested at least once before their 3rd birthday with a result of ≥10 and <20 μg/dL, interpreted for study purposes as "moderately elevated BLL"), or "not exposed" (children tested between 18 and 36 months of age with a BLL of <5 μg/dL; interpreted for study purposes as "never exposed"). A child could only be classified as exposed if they never had a result 20 μg/dL or greater in their lifetime. Similarly, a child classified as not exposed could not have a BLL result of 5 μg/dL or higher at any age.

The BLL records of children in the WCLPPP database who met these definitions were matched with Department of Public Instruction records of 4th-grade WKCE completion. This match produced a list of 5779 children who had taken the WKCE, defined as exposed (3616) or unexposed (2163). Study staff provided this list of students (along with each student's date of birth and BLL information in a coded string indecipherable to non-study personnel) to an MPS data manager to obtain WKCE scores. For the 5779 eligible children, MPS was able to match 3757 in the district with 4th-grade WKCE scores. Those children for whom MPS was unable to find a match had most likely moved out of the district before the 4th grade. Figure 1 shows a flowchart of sample construction.

Student data and characteristics

The MPS returned a deidentified dataset to study researchers. The anonymized dataset of student records included WKCE scores, attendance and suspension data, and information on seven student characteristics including special education status, English Language Learner (ELL) status, race/ethnicity, gender, school attended, and year of birth. All students were listed with a single race/ethnicity status. Eligibility for free or reduced lunch during 4th grade was used as a marker for poverty, and was the only socioeconomic status variable available for analysis.

The leftmost columns in Table 1 show the distributions of student characteristics in our sample. Although recent research suggests important relationships between lead exposure and specific diagnoses associated with special education [24,25], our sample sizes for specific special education designations and uncertainty about the criteria used to determine them prevents reliable conclusions from being drawn. Students receiving any form