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Meng Xu Date

Identifying and Quantifying the Impact of Blood Lead Levels on Academic Performance of Third Grade Children in Evansville, Indiana

By

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Environmental Health

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Thesis Committee Chair: Matthew J Strickland, Ph.D.

An abstract of

A thesis submitted to the Faculty of the

Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of

Master of Public Health

in Environmental Health

2014

Abstract

Identifying and Quantifying the Impact of Blood Lead Levels on Academic Performance of Third Grade Children in Evansville, Indiana

By Meng Xu

Objective: To identify and quantify the impact of blood lead levels on third grade childrens' academic performance on school level basis in Evansville, Indiana.

Method: We conducted an ecological analysis using public data of third grade the Indiana Statewide Testing for Educational Progress-Plus (ISTEP+) test results in ELA and Math of Evansville Vanderburgh School Corporation. Under support of GIS software, we linked 3268 children's blood lead samples from Evansville blood lead testing surveillance data from 2001 to 2004, to 19 public elementary school academic performance scores by school for school year 2010, 2011, and 2012. Controlling for a series of demographic contributors, multivariate linear regression models were established to determine the impacts of high blood lead levels on children's school test results based on the low blood lead levels group and the high blood lead levels group.

Results: Demographic factors such as sex, ethnic, sample type, the year house built and median income are significantly related to children's blood lead levels($p<0.05$). Adjusted for the demographic contributors—the percent of students taking this test and the percent of students who are limited English Proficiency (LEP), a blood lead level$\geqslant$5μg/dL is negatively associated with third grade students English language and arts (ELA) test results ($p<0.04$), Math test results ($p<0.02$) and both these two subjects test results ($p<0.01$), respectively.

Conclusions: Schools with higher percent of with blood lead levels ⩾5μg /dL before the age of 5, had lower third grade students' school performance scores in public elementary school in Evansville, Indiana, after adjusting for key potential confounders.

Key words: Blood lead level, school performance, lead exposure.

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Introduction

Despite much progress made in the prevention, screening, diagnosis, and treatment of lead poisoning, childhood lead exposure continues to be a critical and common public health issue today. A child's environment is full of lead risks; lead-based paint in houses, lead-contaminated soil near streets, and lead-polluted drinking water through plumbing materials are all potential sources of childhood lead exposure [1].

Early lead exposure causes a wide range of adverse health impacts on children, including: hypertension, neurological and renal effects, behavior impairment, learning disabilities, and cognitive defects [2]. Blood lead level (BLL), indicating the concentration of lead in circulating blood, is used to reflect the accumulation of lead in the body. Numerous studies have shown a clear, negative association between elevated BLLs and intellectual function. In a meta-analysis, Schwartz found that IQ can be lowered by 2.6 points on average with an increase of BLLs from 10µg/dL to 20µg/dL [3-4]. The results of more and more studies imply that moderate and even low lead exposure levels contribute to adverse consequences on school test results for young students, with potentially destructive effects on their academic trajectories [5]. Thus, the Centers for Disease Control and Prevention (CDC) decreased the reference blood lead level from 10µg/dL to 5µg/dL in 2012[6]. However, there is a growing evidence showing that learning and behavior defects occur below the reference level of 5µg/dL [7].

The prevalence of elevated BLLs in children in Indiana was 2.9% in 2003, according to Indiana's Childhood Lead Poisoning Prevention Program (ICLPPP) [8]. Older houses were a significant contributor to children's high BLLs. Though the U.S. federal government banned lead-based paint after 1978, most houses in Indiana were built before that time. According to the 2000

Census, Indiana's proportion of housing built before 1950s is 28.3%, which is higher than the national average of 22.3% [9]. Thus, Evansville, Indiana has been select as the targeted city for this study.

No safe blood lead level in children has been identified; thus, it is important to study blood lead levels and school performance [10]. Academic achievement, often strongly predicted by IQ, is a feasible measurement of lead exposure's influence on children's cognitive function. Linking statewide blood lead surveillance data to published data of Indiana's standardized test results among third grade students in public elementary school in Evansville, Indiana, this study investigates the hypothesis of the association between blood lead levels and academic performance of third grade children, controlling for sex, ethnics, socioeconomic status, blood lead sample drawn type and date, and when their family house built.

Methods

This ecological study was conducted under the auspices of Healthy Homes/Lead Poisoning Prevention in the CDC.

School Performance Data

The Indiana Department of Education (IDOE) maintains an open database with records of End-of-Course Assessments (ECAs) for all public school systems in the state for tests from school years 2002 to 2013. Under the No Child Left Behind Act, the Indiana Statewide Testing for Educational Progress-Plus (ISTEP+), the standardized end-of-course test to measure students' educational achievements in the subject areas of English Language Arts (ELA), Mathematics, Science (Grade 4 and 6), and Social Studies (Grade 5 and 7), is mandated by the state of Indiana for students for grades 3 and 8 in elementary schools [11]. The ISTEP+ pass percent refers to the percent of students who successfully pass this test. According to Indiana's Academic Standards, grade 3 students are examined with both ELA and Math. The Evansville Vanderburgh School

Corporation (EVSC) is the third largest school district with approximately 20 public schools in the City of Evansville/Vanderburgh County, Indiana. Grade 3 students ISTEP+ pass percent, along with participation in the free or reduced lunch program, English proficiency, and percent having taken the test in EVSC are extracted from the full dataset in school years 2010 to 2012. These data can be linked longitudinally for all years' test results and on the school level ISTEP+ pass percent.

Blood Lead Data

The State of Indiana's Blood Lead Poisoning Prevention Program manages Evansville blood lead testing surveillance on a volunteer basis. Children under 7 years old in Indiana have their blood drawn in clinics, doctor offices or hospitals. The Mid America Clinical laboratory serves all of Indiana State's BLLs tests, using the method of NexION 300 Inductively Coupled Plasma/ Mass Spectrometry (ICP-MS) with 0.1µg/dL detection and quantification limits for direct analysis of lead in blood [12]. Through a negotiated confidentiality agreement, we can access individual screening data in Evansville from 1992 to 2006 in a full blood lead level dataset. This dataset includes the following variables: identifiers (first and last name, date of birth), sex, ethnicity (White, Black and others), date of blood specimen drawn, sample type (capillary and venous), the year the house was built, age blood lead tested, blood lead level, and median income of the block group (U.S. Census, 2000). Considering the average age for 3rd grade children in US is 8 to 9 years old, we extracted a subset of BLLs of children born in 2001 to 2004 and in the third grade in school year 2010, 2011 and 2012 from the state surveillance data.

Study Sample Construction

GIS (Geographic Information System) software is utilized to link individual BLLs and individual school academic performance assessment by U.S. Census School Attendance Zone tiger files in Evansville. School Attendance Zones, described as catchment areas, are discreet lines drawn around each public school to define which households attend which school [13].Thus, our study can assign individual blood lead levels drawn before 7 years old to the school they are very likely to enroll in when aged 8 to 9 years old among 3rd grade students in Evansville. Under federal court supervision, many school districts implemented mandatory busing plans that transported students to schools outside their neighborhoods within their district to achieve racial and SES balance in the 1970s and 1980s[14]. The Evansville School Bus Company maintains the busing information; about half of the public schools in EVSC include students living in the bused area, which was analyzed in our study.

Statistical Analyses and Modeling

SAS 9.3 statistical software, GIS software, and Microsoft Excel were used for the analyses. The target dataset has 3268 blood lead samples extracted from a total of 10096 in the surveillance system. Data analyses centered on the association between the children's BLLs and their school's academic performance test score with and without adjustment for other demographic contributors [15]. In the blood lead level dataset, the numeric variable age at test, year house built before 1978 or late and median income by quintiles are classified into categorical data. We used a two-sample t-test on the variables of sample type and the year house built to investigate the bivariate relationship of each child characteristic with lead exposure. ANOVA was also applied to test for the remaining variables with multiple categories. Statistical significance was determined by a P-value less than 0.05 or a non-overlapping 95% confidence interval. In the school data set, we average 3-year test results and other demographics, such as free reduced price lunch program (FRLP) and limited English proficiency (LEP) stratified by each school. To be used as an indicator of relative high BLLs, we explored the mean of BLLs ⩾5μg/dL in our study. We used 5μg/dL as the cutoff in our study because 5μg/d L is the current CDC level of concern replacing the previous one of 10μg/dL. The prevalence of the elevated BLLs (BLLs⩾ 10μg/dL) and BLLs ⩾ 5μg/dL of Evansville Children aged 5 years old or younger in our target subset are approximately 2% (64 of 3268) and 32%,(1049 of 3268) respectively. Thus, the elevated BLLs (BLLs⩾10μg/dL) are not regarded as an appropriate indicator of high BLLs due to smaller prevalence based on our dataset. West Terrace Elementary School with only 6 samples would be involved in our analysis, which may result in bias in our study. Next, the left 18 public schools were categorized into quintiles by ranking mean of BLLs ≥5 μg/dL and thus, 4 schools fell into the fifth quintile, as high BLLs group and 4 schools fell into the first quintile, as low BLLs group, to set up two comparison groups which were then tested for the significant difference by a two-sample t-test using SAS version 9.3. Additionally, to better explore the trend of the association, we also tested on the 3 schools with high BLLs versus 3 schools with low BLLs; and 5 schools with high BLLs versus 5 schools with low BLLs.

Since our outcome ISTEP+ pass percent was continuous variable, the multivariate linear regression models for ELA, Math and both ELA and Math were conducted relying on eight schools (two comparison groups), respectively, adjusted for all the potential confounders in our data set. We used Stepwise Selection method to build up three predictive models for three schools ISTEP+ test results by setting default entry and stay criterions (0.1 entry and stay criterions in all three models). Diagnostic measures to check assumptions for linear regression models were performed to check for the outliers and to minimize multicollinearity between predictors.

Results

Blood Lead Sample Representatives

A total of 3,268 blood level specimens were drawn from children aged 1-5 years in Evansville, Indiana, 2001-2004.

Figure 1 presents the boundaries of 19 school attendance zones of public elementary schools our study areas. The location of schools which receive bussed students is also described in the map.

Figure 2 reveals the location of all blood lead samples coming from. BLLs above 5 μg/dL and BLLs below quantification limit are all shown in the map with red and yellow dots, respectively.

Table 1 provides summary statistics on the demographics of the target sample among 1-5 year-old children. The number of BLLs, mean and standard deviation of BLLs of each subgroup are all listed in the table. The sample was approximately 52% male and over 93% of the children's blood samples were drawn by capillary type. Information on ethnicity was available for 66.19%; nearly 12% were Black. A large percentage, nearly 88% of houses, was built before 1978. More than 77% of the children were tested at between 12 to 24 months (1-2 years old). The annual median income quintile of the block group (U.S. Census, 2000) in Evansville was \$20,491 (20^{th} percentile), \$25,685 (40^{th} percentile), \$31,739 (60^{th} percentile) and \$37,819 (80^{th} percentile) and the median income almost equally distributed (around 20% for each one). There was an association between BLLs and sex (ANOVA: 3.35; P-value: 0.0351), BLLs and ethnicity (ANOVA: 4.38; P-value: <.0001), BLLs and sample type (TTEST: 1.79; P-value: <.0001), BLLs and the year house was built (TTEST: 1.81; P-value: <.0001), and BLLs and median income (ANOVA: 11.89; P-value: <.0001). However, mean BLLs in each age subgroup are not significantly different, so no any association was found between BLLs and age at test (ANOVA: 1.92; P-value: 0.1038).

Figure 3 show the histogram of arithmetic mean in BLLs among 1-5 year-old children in Evansville, Indiana, 2001-2004. The distribution of BLLs was highly skewed to the right with arithmetic mean BLLs 3.28 μg/dL (SD=3.57 μg/dL) based on 3,268 observations. The range of BLLs varied from 0μg/dL to 51μg/dL. Relying on the detection and quantification limits, over 30% blood lead samples in the data set are recorded as 0μg/dL. Approximately 25% blood lead samples have BLLs of μg/dL and very few blood lead samples are above 10μg/dL. Additionally, the geometric mean BLLs is 1.54 μg/dL (SD=0.43 μg/dL).

Third Grade School Performance

Table 2 describes the average ELA, math and both subjects ISTEP+ Pass percent and their demographic contributors among third grade children in 19 public elementary schools in Evansville Vanderburgh School Corporation (EVSC), school year 2010-2012. There were two missing variables of free or reduced-price lunch program (FRLP) and limited English proficiency (LEP) in Glenwood Leadership Academy. The average ISTEP+ test results varied greatly in ELA, math and both subjects among 19 public schools in Evansville. No big difference could be found in LEP, but the percent of children who were in the FRLP may be as low as 26.8% or as high as 97.6% in different schools.

Effect of Lead on ISTEP+ Test Scores

Table 3 shows the number of BLLs samples, mean of BLLs and mean of BLLs ≥ 5 µg/dL classed by public schools in Evansville. Nearly 50% of students in public schools were bused to meet the racial balance in EVSC. The samples of BLLs ≥ 5µg/dL extracted were tremendous small in West Terrace Elementary Schools. Mean of BLLs≥ 5 µg/dL is ranged from 5.88µg/dL to 7.91µg/dL, while mean in BLLs of children in each school varied from 2.1µg/dL, to 4.65µg/dL.

Table4 summarizes all response variables including ISTEP+ test results, high BLLs indicator, and demographic factors in two comparative groups with relatively low and high BLLs chosen from 19 elementary schools in Evansville. We excluded West Terrace Elementary School because the extremely small sample size may cause bias in our later analysis. Thus, 18 schools were categorized into quintiles by ranking mean of BLLs ≥5 µg/dL that 4 schools (Vogel, Hebron, Highland and Lodge) fell into first quintile named low BLLs group and 4 schools (Lincoln, Cedar Hall, Daniel and Glenwood) fell into the fifth quintile named high BLLs group. The mean of BLLs of 5 and above in low BLLs group ranged from 5.88 µg/dL to 6.2 µg/dL , while the mean of BLLS of 5 and above in high group is from 6.98µg/dL to 7.91µg/dL. Average test results, percent of third grade students taking the tests, FRLP, and mean median income varied obviously in these 8 schools.

Table 5 concludes the crude measures of the association between high BLLs and overall performance, including mean in ELA, math and both test results classified by low BLLs and high BLLs groups mentioned above, and four schools listed in each group. The results demonstrate the association for ELA, math and both tests with high mean BLLs indicated by mean BLLs≥ 5 μg/dL; the school-level ISTEP+ test results were worse. Analysis of a two-sample T-Test indicated that there are significant differences in average ISTEP+ pass percent between these two BLLs comparison groups were significant in ELA, Math and Both (P-value in average ELA: 0.05; P-value in average Math: 0.04; P-value in average Both: 0.03).

In addition, to better explore the trend of association, we considered the association between high BLLs and academic performance by classing 3 schools in each group (high BLLs versus low BLLs) and 4 schools in each group (high BLLs versus low BLLs) as well. At a 5% significance level, there is negative association between high BLLs and school performance in Math and Both test results by grouping 3 schools in each group ((P-value in average ELA: 0.1; P-value in average Math: 0.004; P-value in average Both: 0.01).Similarly, at a 5% significance level, there is negative association between high BLLs and school performance in Math and Both academic results by grouping 4 schools in each group (P-value in average ELA: 0.08; P-value in average Math: 0.046; P-value in average Both: 0.046).

Table 6, table 7 and table8 present adjusted results of the multivariate linear regression model for Schools ISTEP+ pass percent in ELA, Math and Both test results, controlling for demographic covariates listed in the Table1 and Table 2, respectively. The reference group is defined as white, female students, whose blood lead sample is drawn by venous, whose house is built after 1978, who do not participate in the free or reduced-price lunch program and is not limited English proficiency. The coefficient on BLLs group (high BLLs group coded as 1versus low BLLs group coded as 0) is negative and statistically significant ($p<0.04$ in ELA results, $p<0.02$ in Math results, $P<0.01$ in Both results), indicating that a higher blood lead level has adverse impacts on students' academic performance at their later age. LEP, as a strong indicator of SES, negatively relates to overall school test results. The percent of taking the corresponding test is also correlated to the recorded test results in our dataset.

Discussion

This is the ecological study in that we focused on the comparison of groups at school level, rather than individuals. Thus, the variables prepared for building up models are school level predictors. The arithmetic mean of BLLs is not normally distributed because blood lead values are truncated at 0.25. Among all public elementary schools in EVSC, very few children's BLLs are 10μg/dL and above. However, the prevalence of BLLs of 5 μg/dL and above varies from 20% to 50%, indicating large quantity of students with relatively high blood lead level. We found a significant association between early childhood lead exposure and children overall school performance in EVSC public schools in ELA, Math and Both these two subjects, which is similar to from previous studies [16]. The reason we used quintile to classify our high BLLs group and low BLLs group was to use extreme conditions to set up comparison groups. We cannot analyze all 19 schools because we do not have enough school to establish the school level test results into continuous variable. Since our sample size is only eight when building up regression models, the large standard deviation may affect our significant results. For example, P values for ELA and Math are 0.5 and 0.4 in our crude measures of association, respectively. However, it will definitely become much smaller and significant when we increase our sample size. Family median income and free or reduce priced lunch program are correlated with each other in our regression model, so take them out in the final model to avoid multicollinearity.

Though our results are broadly consistent with previous research of the early childhood lead exposure on cognitive functioning, our study develops new methodology to work on the impacts of high blood lead level on school performance with access to limited data. Researchers have great difficult to get individual student test scores due to privacy laws. In addition academic performance at the school rather than the student level has important policy implications and is a useful means for targeting resources to under performing schools. Understanding the effect of factors outside the control of the education community is a critical step to developing strategies that will advance the nation's ambitious academic goals.

Thus, combining limited school level data and children BLLs by utilizing GIS and SAS is a breakthrough. Our study also has the strength of using busing information. In 1969, the new policy was promulgated to mix African American children with white children together within school districts to achieve racial and SES balance. Thus, considering busing information in our analysis may increase credibility and accuracy of our results.

In this study, we have several important limitations that must be acknowledged. First, our sample size is small, which affected the accuracy of model building. Second, our BLLs surveillance data is volunteer basis that may lead to bias. However, the bias could be two directions. Children with high BLLs may be more likely to see the doctor to get blood lead tests. Or children with high BLLs are more likely in the poor families and theses families are possibly disorganized or illegally immigrated, resulting in absence of their children in the health care system.

Conclusions and Recommendations

Schools with higher percent of with blood lead levels ≥5μg /dL before the age of 5, had lower third grade students' school performance scores in public elementary school in Evansville, Indiana, after adjusting for key potential confounders. To our best knowledge, our study developed a new methodology to link individual blood lead samples to school-level academic performance.

Our findings shed light on the prevention and intervention of early childhood exposure in Evansville. It increased the awareness of health impacts of lead poisoning on children among parents, school administrators and teachers. New policies are encouraged to promulgate to enhance primary prevention of lead exposure in Evansville, Indiana.

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Tables & Figures

Figure1. Map of Evansville Vanderburgh School Corporation (EVSC) in City of Evansville/ Vanderburgh County, Indiana

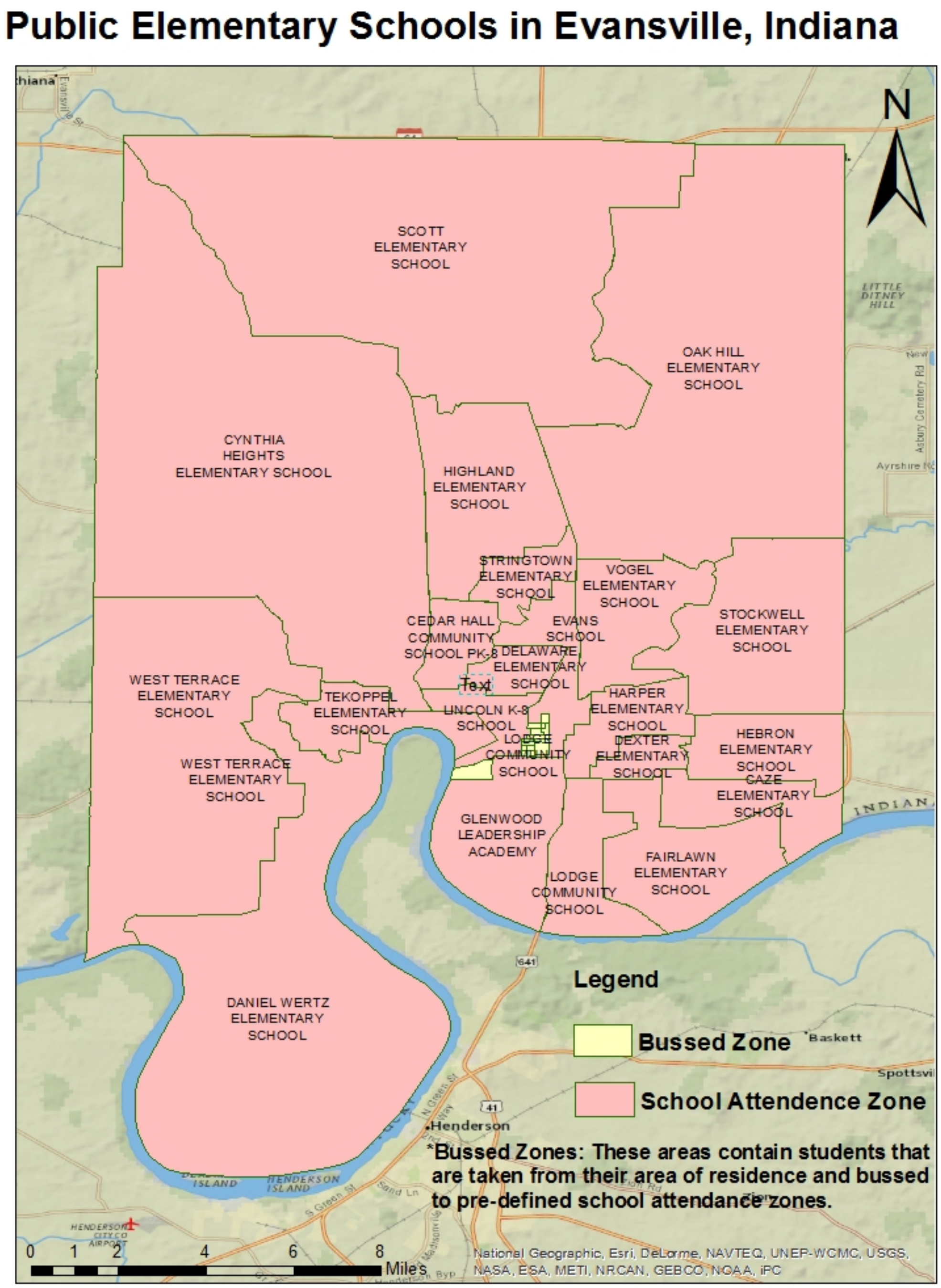

Figure2. Location and Distribution of Children's Blood Lead Samples, Evansville, Indiana

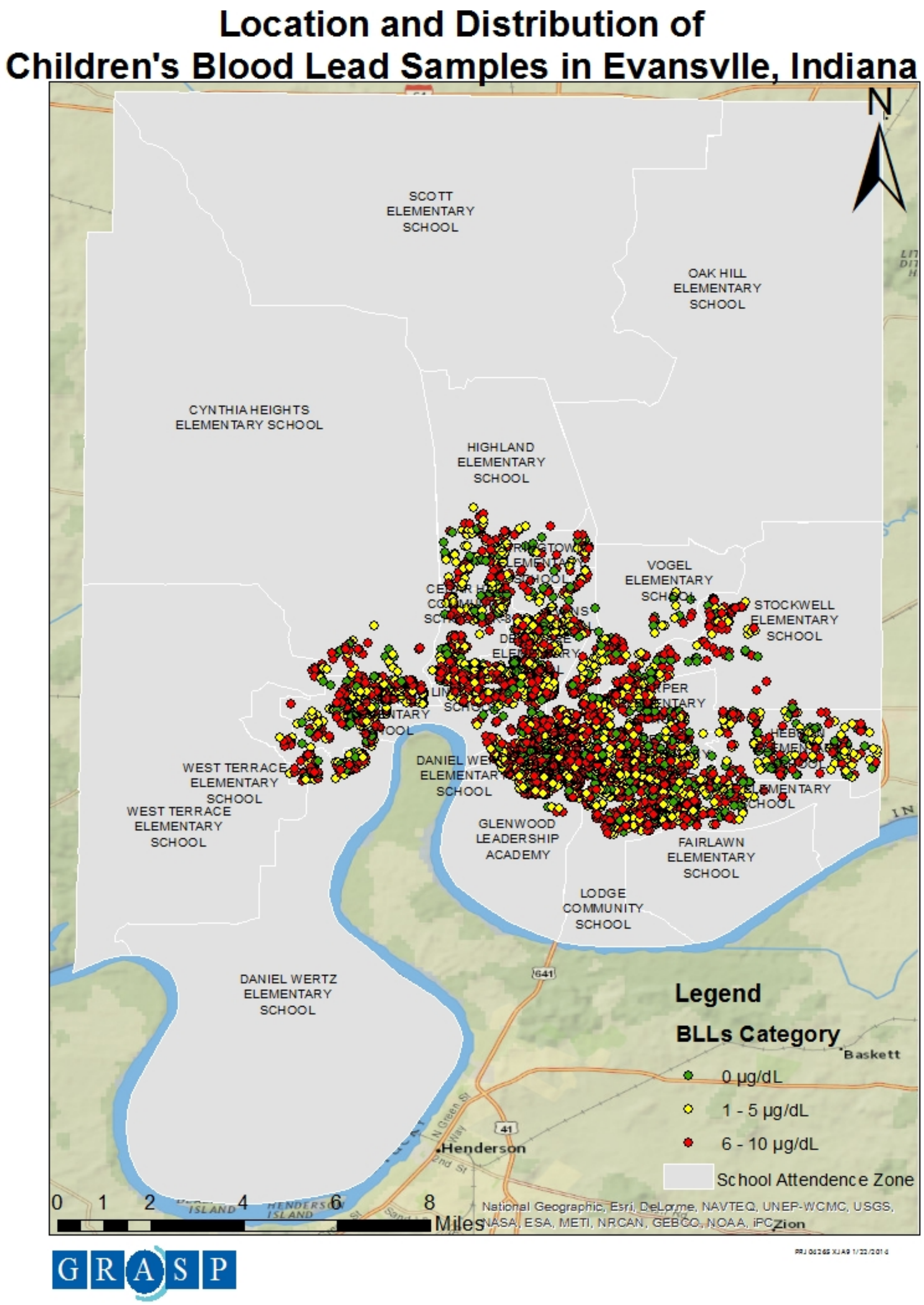

Table1. Sample Characteristics- Evansville, Indiana, 2001-2004

Variable	Percentage	# of BLLs Sample	Mean BLLs (SD, μg/dL)	Statistic (*P*)
Sex				3.35 (0.0351)
Female	47.55	1554	3.24 (3.74)	
Male	51.62	1687	3.34 (3.42)	
Uncertain	0.83	27	1.59 (2.27)	
Ethnicity				4.38 (<.0001)
White	2.47	80	2.41 (1.99)	
Black	11.96	379	3.36 (3.49)	
Other	0.68	22	3.95 (2.17)	
Unknown	9.87	320	3.03 (3.02)	
American Indian/Asian/White	3.67	119	3.55 (3.44)	
American Indian/Asian/White	36.83	1194	3.39 (3.96)	
American Indian/Asian/Black/Native Hawaiian/White	0.99	32	6 (0.00)	
Code Error, Unknown	33.81	1096	3.10 (3.40)	
Sample Type				1.79 (<.0001)
Capillary	93.18	3045	3.26 (3.48)	
Venous	6.82	223	3.47 (4.65)	
Year House Built				1.81 (<.0001)
Before 1978	87.64	2864	3.34 (3.67)	
After 1978	12.36	404	2.83 (2.72)	
Age at Test (Month)				1.92 (0.1038)
[0, 12)	2.72	89	3.24 (3.18)	
[12, 24)	77.66	2538	3.35 (3.75)	
[24, 36)	10.5	343	2.90 (2.96)	
[36, 48)	5.81	190	2.87 (2.68)	
[48,66)	3.3	108	3.43 (2.26)	
Median Income ($)				11.89(<.0001)
[9770,20491)	19.92	651	3.67 (3.62)	
[20491,25685)	18.97	620	3.50 (4.04)	
[25685,31739)	20.62	674	3.58 (3.77)	
[31739,37819)	20.13	658	3.14 (3.23)	
[37819,70674)	20.35	665	2.51 (2.99)	

Note. BLL=blood lead level; the total sample size was n=3,268 children.

Figure3. Histogram for Arithmetic Mean in BLLs among 1-5 year-old Children in Evansville, Indiana, 2001-2004

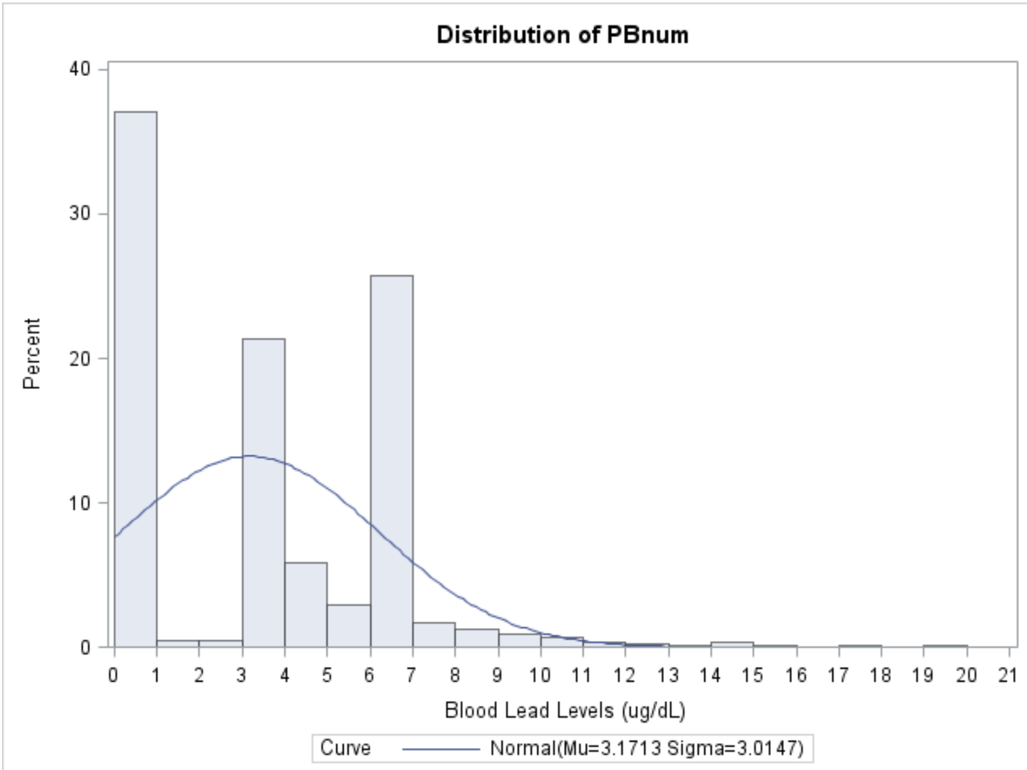

Table2. Statistics of Third Grade Students School Performance and Demographic Contributors in EVSC, Indiana, School Year 2010-2012

School Name	Average ELA Pass (%)	Average Math Pass (%)	Average Both Pass (%)	% of Taking ELA	% of Taking Math	% of FRLP	% of LEP
Caze	59.00	46.00	42.67	54.39	41.62	85.30	4
Cedar Hall	63.67	52.33	46.33	56.75	43.66	90.80	0.60
Cynthia Heights	86.33	80.67	76.33	81.44	70.63	40.50	0.60
Daniel Wertz	74.67	53.00	49.00	74.63	51.28	72.60	0
Delaware	64.00	43.67	42.33	60.67	39.21	94.80	0.90
Dexter	65.67	58.00	56.00	55.91	49.64	80.30	2
Evans	54.00	54.67	45.67	54.15	53.30	97.60	1
Fairlawn	68.00	59.00	54.00	66.38	53.09	82.50	0
Glenwood Leadership	49.5	48.25	37.75	47.94	47.68	NA	NA
Harper	75.33	71.67	64.00	100.00	92.46	69.90	0.80
Hebron	85.33	82.33	78.67	77.27	68.28	45.60	3
Highland	89.67	88.00	85.67	79.11	71.19	35.60	2
Lincoln K-8 School	58.33	39.33	34.33	56.97	37.19	95.00	2
Lodge	63.33	48.00	43.67	55.72	38.69	88.90	10
Stockwell	81.67	65.67	63.00	74.44	60.76	68.30	8
Stringtown	79.00	74.00	67.67	76.93	70.13	62.50	0.50
Tekoppel	73.67	61.67	59.67	70.40	54.19	75.80	0.60
Vogel	82.67	74.67	71.00	71.00	57.85	62.40	2
West Terrace	93.67	90.33	89.33	82.97	75.46	26.80	0

Note. ELA=English Language and Arts; FRLP= Enrolled in free or reduced-price lunch program; LEP= Limited English Proficiency.

Table 3 Statistics of Number of Blood Lead Samples, Mean Blood Lead Levels and Mean Blood Lead Levels of 5µg/dL and above Stratified by Schools in Evansville, Indiana, 2001-2004

School Name	Bused School	# of BLLs Samples	BLL (µg/dL) Mean (SD)	BLLs ≥5 (µg/dL) Mean (SD)
Evans School	No	250	3.32 (3.04)	6.53 (2.05)
Caze Elementary school	YES	244	2.9 (2.88)	6.32 (2.07)
Cedar Hall Community School	No	315	3.28 (4.64)	7.43 (6.03)
Cynthia Heights School	No	59	3.1 (2.92)	6.67 (1.97)
Daniel Wertz Elementary School	YES	82	3.01 (4.95)	7.78 (7.44)
Delaware Elementary School	YES	215	3.67 (3.01)	6.72 (2.01)
Dexter Elementary School	YES	250	2.38 (2.78)	6.35 (1.40)
Fairlawn Elementary School	YES	154	2.71(2.65)	6.20 (1.37)
Glenwood Leadership Academy	No	396	4.65 (5.05)	7.91 (5.55)
Harper Elementary School	YES	223	2.93 (2.78)	6.25 (1.52)
Hebron Elementary School	YES	190	2.1 (2.54)	6.12 (0.54)
Highland Elementary School	YES	63	3.05 (2.83)	6.16 (0.62)
Lincoln K-8 School	No	279	3.93 (3.3)	6.98 (2.51)
Lodge Community School	YES	108	2.9 (2.64)	6.21 (0.88)
Stockwell Elementary School	No	153	3.25 (2.85)	6.24 (1.21)
Stringtown Elementary School	YES	68	3.22 (3.29)	6.78 (2.84)
Tekoppel Elementary School	No	148	3.26 (3.57)	6.95 (2.98)
Vogel Elementary School	No	65	2.94 (2.64)	5.88 (0.33)
West Terrace Elementary School	No	6	3.00 (3.29)	6 (0)

Note. BLLs= Blood Lead Levels.

Table4. Comparison of BLLs Indicators, Test Results in ELA, Math and Both and Demographic Factors in Two Groups of Schools with Low BLLs Versus High BLLs (n_{low}=4, n_{high}=4)

Response Variable	Low BLLs Group				High BLLs Group			
	Vogel	Hebron	Highland	Lodge	Lincoln K-8	Cedar Hall	Daniel Wertz	Glenwood Leadership
Mean BLLs ≥5 (µg/dL)	5.88	6.12	6.16	6.2	6.98	7.43	7.78	7.91
Average ELA (%)	87.67	85.33	89.67	63.33	58.33	63.67	74.67	49.5
Average Math (%)	74.67	82.33	88	48	39.33	52.33	53	48.25
Average Both (%)	71	78.67	85.67	43.67	34.33	46.33	49	37.75
% of Taking ELA	71	0.77	79.11	55.72	0.57	56.75	74.63	0.48
% of Taking Math	57.85	0.683	71.19	38.69	0.372	43.66	51.28	0.477
Male (%)	47.69	48.95	42.86	58.33	54.48	52.38	50	51.01
Black (%)	9.23	11.64	4.76	20.56	13.98	14.33	9.76	10.59
Capillary (%)	95.38	92.63	87.3	91.67	92.83	95.87	93.9	89.65
Before 1978(%)	89.23	75.26	92.06	90.74	83.87	74.92	86.59	92.42
FRLP (%)	62.4	45.6	35.6	88.9	95	90.8	72.6	95
LEP (%)	2	3	2	10	2	0.6	0	3
Mean Median Income ($)	36372	48184	39608	29156	17336	20640	34553	26434
Mean Age at Test (Month)	17	16	14	20	19	18	16	19

Table5. Crude Measures of Association of Schools 3rd Grade Average ISTEP+ Test Results (ELA, Math and Both) and Blood Lead Levels by Comparison of High BLLs Group Versus Low BLLs Group

Variable	BLLs Group	Mean (SD)	95% CI	P-value
Average ELA	High BLLs	61.54 (10.52)	(44.80, 78.28)	
	Low BLLs	80.25 (11.64)	(61.73, 98.77)	0.05
	Difference	-18.71 (11.10)	(-37.91, 0.49)	
Average Math	High BLLs	48.23 (6.29)	(38.21, 58.24)	
	Low BLLs	73.25 (17.70)	(45.09, 101.4)	0.04
	Difference	-25.02 (13.28)	(-48.00, -2.04)	
Average Both	High BLLs	41.85(6.94)	(30.81, 52.90)	
	Low BLLs	69.75 (18.39)	(40.48, 99.02)	0.03
	Difference	-27.90 (13.90)	(-51.95, -3.85)	

Table6. Results of Multivariate Linear Regression Model for Schools 3rd Grade Students ELA Test Results Adjusted for the Key Demographics

Response Variable	Coefficient	P>t	95% CI
Constant	45.56	0.03	(9.09, 82.03)
BLLs Group (High=1, Low=0)	-17.87	0.04	(-28.20,-7.53)
% of Taking ELA	45.56	0.02	(0.18, 1.05)
LEP	-1.77	0.04	(-3.39, -.015)
Adjusted R^2	0.97		
Root MSE	2.44		

Table7. Results of Multivariate Linear Regression Model for Schools 3rd Grade Students Math Test Results Adjusted for the Key Demographics

Response Variable	Coefficient	P>t	95% CI
Constant	30.06	0.07	(-4.68, 64.8)
BLLs Group (High=1, Low=0)	-17.42	0.02	(-29.87, -4.96)
% of Taking Math	0.84	0.01	(0.36, 1.31)
LEP	-1.46	0.09	(-3.29, 0.38)
Adjusted R^2			
Root MSE			

Table8. Results of Multivariate Linear Regression Model for Schools 3rd Grade Students Both ELA and Math Test Results Adjusted for the Key Demographics

Response Variable	Coefficient	P>t	95% CI
Constant	36.90	0.06	(-2.17, 75.98)
BLLs Group (High=1, Low=0)	-24.08	0.01	(-38.08,-10.07)
% of Taking Math	0.71	0.02	(0.18, 1.24)
LEP	-2.17	0.04	(-4.23, -0.11)
Adjusted R^2	2.96		
Root MSE	2.96		