Journal of Community Medicine & Public Health
Ridzi FM and Cyrus CA. J Community Med Public Health 10: 580
www.doi.org/10.29011/2577-2228.100580
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Research Article

Revisiting Lead Exposure's Negative Impact on Test Scores: What Can Neighborhoods Tell Us?

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Citation: Ridzi FM, Cyrus CA (2026) Revisiting Lead Exposure's Negative Impact on Test Scores: What Can Neighborhoods Tell Us? J Community Med Public Health 10: 580. DOI: https://doi.org/10.29011/2577-2228.100580

Received Date: 18 August, 2026; **Accepted Date:** 28 August, 2026; **Published Date:** 31 August, 2026

Abstract

Lead paint in deteriorating housing remains a severe public health crisis across the United States in legacy cities such as Syracuse, New York, where most homes predate the 1978 federal ban. While previous research links lead exposure to diminished academic performance, prior studies relied on county-wide data and higher blood lead level thresholds. This study shifts the focus to a neighborhood level and utilizes lower blood lead levels to define lead poisoning. Specifically, this study investigates the relationship between neighborhood lead poisoning rates and third-grade standardized ELA assessment performance in Syracuse. Using bivariate and multiple regression models, the study treats ELA scores as the dependent variable and lead poisoning rates as the independent variable, while controlling for potential socio-economic effects: household English proficiency and rent burden. The findings reveal a moderate positive correlation ($r = 0.38$, $p < .05$) between neighborhood lead poisoning rates and substandard ELA proficiency. For every one-percent increase in lead poisoning, substandard ELA proficiency increased by 0.73 percentage points. Lead poisoning remained a significant predictor of low ELA performance when controlling for household English proficiency ($p < .05$), and maintained marginal significance ($p < .1$) when controlling for rent burden. Ultimately, these results underscore lead poisoning as a critical issue of both public health and educational equity. It establishes housing as a key social determinant of education, demonstrating that targeted policies addressing lead exposure and healthy housing are vital to protecting children's cognitive health, improving long-term wellbeing, and fostering upward economic mobility.

Keywords: Lead exposure; ELA proficiency; Rent burden; Neighborhoods; Childhood education; Economic mobility

Introduction

Assessments indicate that more than 90% of housing units in Syracuse were constructed prior to the 1978 federal ban on lead-based paint. Due to the city's aging housing stock, children in Syracuse face an elevated risk of lead exposure, most commonly through deteriorating paint, and dust in older homes. Historically, nearly 10% of children in the city exhibited toxic blood lead levels. This figure has declined by almost half since 2012 due in large part to increased public health outreach and interventions; however, lead exposure remains a persistent and acute public health concern. These risks disproportionately affect children living in low-income neighborhoods with older housing and significantly more limited resources.

At the same time, academic outcomes among children in Syracuse remain a concern. Only approximately 17% of third-grade students enrolled in the Syracuse City School District (SCSD) meet proficiency standards in English Language Arts (ELA), as measured by New York State standardized assessments. This sharply contrasts with proficiency rates of roughly 45% state-wide and in suburban school districts within Onondaga County. Early literacy is a well-established predictor of later academic success, and disparities in third-grade ELA achievement are strongly

linked to long-term educational attainment and upward economic mobility. Given existing evidence tying environmental exposures to cognitive development and learning outcomes, the coexistence of elevated lead poisoning rates and low ELA proficiency in Syracuse raises important questions about their potential relationship. Building on prior research that has established a causal association between lead exposure and academic outcomes, this study aims to determine the relationship between childhood lead poisoning and third-grade ELA proficiency within SCSD, at the neighborhood level. The study is anticipated to conclude that there is a strong correlation between these two variables.

A substantial amount of previous research has documented the adverse health consequences of lead exposure in children, prompting sustained public health messaging for parents aimed at prevention, screening, and remediation. Lead is a noted neurotoxin with no safe level of exposure; its effects are particularly damaging during early childhood, when the brain is rapidly undergoing development. In addition to immediate physical and neurological impacts, researchers have increasingly emphasized the long-term social and economic consequences of lead exposure in one's early life. Those consequences extend beyond individual outcomes to affect families, neighborhoods, and broader society.

Prior research has determined that lead exposure in childhood is associated with increased rates of antisocial and criminal behavior in adulthood, particularly in highly resource-deprived contexts [1,2]. Muennig [3] similarly found that substantial reductions in childhood blood lead levels were associated with declines in crime rates and increases in on-time high school graduation. These findings suggest that lead exposure may shape the trajectory of a child's life by impacting cognitive and behavioral regulation in adolescence, thereby increasing the likelihood of adverse outcomes in multiple areas. Other analyses have estimated that the economic costs of childhood lead poisoning reach into the hundreds of billions of dollars, accounting for expenses related to medical treatment, special education services, reduced lifetime earnings, and criminal justice involvement [4]. Collectively, the literature highlights lead exposure as a major contributor to both health inequities and structural socioeconomic disadvantage.

The cognitive impacts of lead exposure are especially pertinent for understanding disparities in educational achievement. Abelsohn and Sanborn [5] concluded that lead exposure impairs both motor function and fundamental cognitive processes, including memory, attention, and executive functioning. These impairments directly affect children's ability to acquire skills in literacy, classroom learning, and perform on standardized assessments. Historically, many studies have defined elevated blood lead levels using a threshold of 10 μg/dl. However, more recent research has shown that adverse cognitive and academic effects occur well below this level, challenging earlier assumptions about what level of lead exposure is considered "safe".

Chandramouli et al. [6], for example, found that children with blood lead levels between 5 and 10 μg/dl experienced significant declines in educational achievement, including lower reading and writing scores. While their study did not focus exclusively on third-grade students or standardized ELA testing, it provides critical evidence that relatively low levels of lead exposure can negatively affect academic performance. Consistent with this evolving scientific consensus, the scientific community has begun to apply a lower threshold for identifying elevated blood lead levels. Onondaga County's Lead Poisoning Prevention Program, which supplies data for the present study, defines elevated blood lead levels as 5 μg/dl, a standard adopted in this analysis.

Needleman's [7] longitudinal research further reinforces the conclusion that low-level lead exposure has lasting consequences. By following individuals identified as having been exposed to lead in childhood, Needleman demonstrated significant deficits in cognitive functioning—particularly in IQ and attention—persisting into young adulthood. These findings established that even exposure levels once considered low-risk could result in enduring neurological harm. Importantly, the present study extends this work by focusing on blood lead levels measured when children are first tested at ages one and two. This earlier developmental window is critical, as neurological impacts during infancy may have especially profound and lasting effects on later learning and academic achievement. By examining exposure at this stage, the study underscores the importance of early detection and intervention in preventing long-term educational consequences.

This research is also informed by Strayhorn and Strayhorn's [8] county-level analysis of lead exposure and standardized test performance across New York State. Using data from the New York State Department of Health, the U.S. Census Bureau, and the New York State Department of Education, their study identified a significant association between blood lead levels and academic outcomes while accounting for income a as control variable. Methodologically, the present study adopts a similar approach by averaging lead exposure over multiple years and comparing it to standardized test performance in later years. However, the Strayhorns' analysis included eighth-grade math scores and relied on cross-county comparisons, which may obscure important variations across both school districts and neighborhoods.

This study builds on and extends the Strayhorns' work in several important ways. First, it focuses on Syracuse, a high-poverty community with persistent lead exposure risks, allowing for a more detailed examination of neighborhood-level disparities. Second, the analysis is conducted at the census tract level, enabling assessment of neighborhoods in both lead exposure and ELA

proficiency within the city. Third, the study incorporates refined confounding factors—specifically household English language proficiency and rent burden—as proxies for socioeconomic status and housing instability. Finally, by holding the school district constant, this research mitigates confounding effects associated with differences in curriculum and instructional priorities. This design isolates neighborhood-level dynamics and reduces the urban–rural and inter-district variation inherent in county-level analyses. As a result, the study offers a more precise assessment of the relationship between early childhood lead exposure and third-grade ELA proficiency among children in Syracuse.

Materials and Methods

The protocol for this study was reviewed and approved by the LeMoyne College Institutional Review Board (IRB). Provided that this research involved analysis of de-identified administrative records, the study was determined to pose little to no risk to participants.

While the New York State Department of Education (NYSED) reports 3rd grade ELA proficiency rankings, this information is only provided via school report cards on the NYSED website. These data are not available by census tract, which previously limited researchers' ability to examine neighborhood dynamics.

Through a partnership between SCSD and the Central New York Community Foundation, this study disaggregated the NYSED data at the census tract level. Census tracts were chosen as the unit of analysis rather than zip codes, which are more commonly available, because census tracts provide a more granular understanding of neighborhood variation. A zip code may encompass multiple census tracts with varying levels of lead poisoning. Therefore, disaggregating the data allowed individual neighborhoods to be used as units of analysis. Because there are 52 census tracts in the City of Syracuse, the sample size for this study was n = 52. Because the census tracts are spread across the city's boundaries, there is no risk of selection bias. Data for both control variables were drawn from the American Community Survey (ACS) (5-Year Estimates).

The Onondaga County Health Department's Lead Poisoning Prevention Program provides lead poisoning data by neighborhood. Lead poisoning data have been available since 2013. This study uses the average rate of elevated blood lead levels per census tract from 2015-2017 as the independent variable. Onondaga County's definition of elevated blood lead levels (≥ 5μg/dL) serves as the definition for lead poisoning in this model. Physicians in New York State are required to test children for lead poisoning at ages one and two; therefore, children tested in the years 2015-17 would be in third grade around 2021-23. ELA proficiency scores were averaged across the years 2021 through 2023 by census tract.

NYSED defines substandard ELA proficiency as scoring in the range of Level 1 or Level 2 on standardized ELA assessments. While Level 2 is on track to graduate, it does not meet NYSED's standards of proficiency, according to a 2021 press release.

Previous studies [5] have demonstrated that the age at which a child is exposed to English is positively associated with language scores later in life, while Yel et al.'s findings [9] suggest that there is a moderate relationship between use of English at home and children's scores on standardized academic tests (albeit in fifth grade in that study). Given Syracuse's sizeable population of recent immigrants and New Americans, where many languages are spoken in households, our study accounts for the average level of English proficiency at the household level. Utilizing the ACS 5-Year Estimates across the years 2017-2021, the model controls for the average percentage of households in the census tract where no member 14 years or older speaks only English or speaks a language other than English but still speaks English very well (ACS definition).

Similarly, our study accounts for rent burden, defined as the average percentage of a census tract's population spending greater than 30% of household income on rent from 2016 to 2020. Previous research [10] identified that lower household income is associated with reduced school readiness among children. Accordingly, we suggest that families who spend more on housing – and consequently have less disposable income – may have children who perform lower on standardized ELA assessments. Data on the percentage of families' income spent on housing from 2016 to 2020 were obtained from the ACS 5-Year Estimates.

Results

Table 1 presents the variables' descriptive statistics. The average lead poisoning rate of 10% (SD = 6%) was significantly higher than the national average, known to be around 2.5% [11]. On average, 78% (SD = 12%) of third-graders tested below proficiency in ELA. Both lead poisoning and household English level were significantly skewed to the right, suggesting that some census tracts exhibit higher levels of lead poisoning and lower household English levels. Nearly half of the residents are rent burdened, a trend consistent with national findings [12]. This overview provides context for understanding neighborhood-level conditions in Syracuse.

Variable	Mean	Median	Std. Dev.	Skewness	n
ELA Proficiency	78%	80%	12%	-0.874	52
Lead Poisoning	10%	8%	6%	0.667	52
Household English	5.71%	2.90%	6.28%	1.466	52
Rent Burden	49%	52%	15%	-0.529	52

Table 1: Descriptive Statistics.

Pearson correlations among the variables are shown in Table 2. Lead poisoning was positively associated with substandard ELA proficiency at a modest level ($r = 0.381$, $p < .05$). Similarly, household English level had a moderate positive correlation with substandard ELA proficiency ($r = 0.351$, $p < .05$). Rent burden was not significantly associated with substandard ELA proficiency ($r = 0.195$). Household English was not significantly correlated with lead poisoning ($r = 0.378$), nor was rent burden ($r = 0.181$). Lastly, rent burden had a small, nonsignificant relationship with household English ($r = 0.099$).

Variable	1	2	3	4
1.ELA Proficiency	-	-	-	-
2.Lead Poisoning	0.381*	-	-	-
3.Household English	0.351*	0.378	-	-
4.Rent Burden	0.195	0.181	0.099	-
Note: * = $p < 0.05$				

Table 2: Pearson Correlation Among Variables.

The independent variable was the average lead poisoning rate per census tract from 2015 to 2017, and the dependent variable was the average percentage of third-grade students with substandard ELA proficiency from 2021 to 2023. A bivariate linear regression was conducted to examine the relationship between lead poisoning and substandard ELA proficiency, with the results presented in Figure 1.

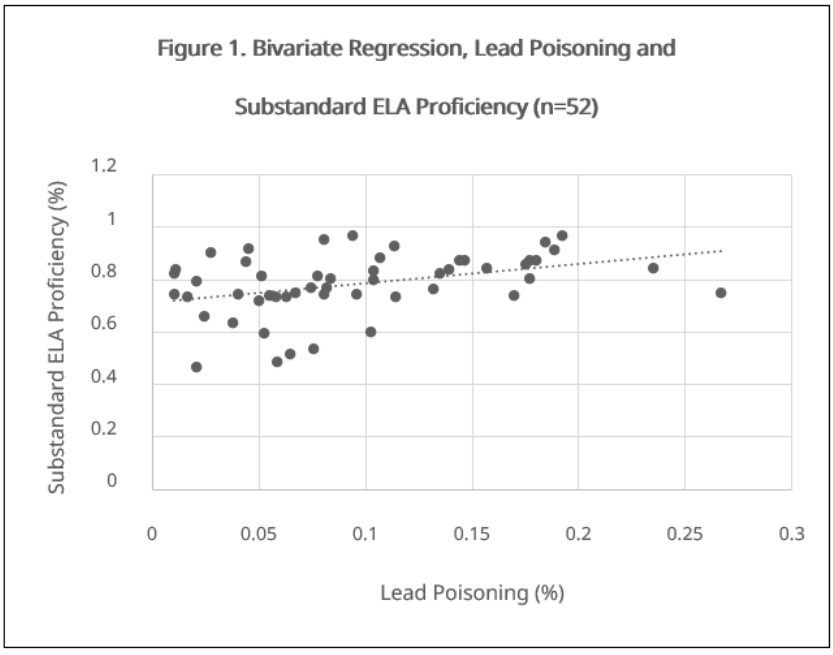

Figure 1: Bivariate Regression, Lead Poisoning and Substandard ELA Proficiency (n=52).

Lead poisoning accounted for approximately 14.6% of the variance in substandard ELA proficiency ($R^2 = 0.146$). These results suggest that other factors may contribute to variation in ELA proficiency and ought to be considered in multivariate analyses.

A multivariate regression was used to determine if lead poisoning, accounting for household English level, predicted substandard ELA proficiency. As seen in Table 3, the overall model was significant, $F(2, 49) = 5.95$, $p = .0049$, and explained around 16% of the variation in substandard ELA proficiency (Adjusted $R^2 = .163$). In this model, lead poisoning remained a significant predictor: a one percent increase in lead poisoning was associated with a .56-percentage point-increase in substandard ELA proficiency ($p = .040$). In contrast, household English was not a significant predictor ($p = .089$). These results highlight the importance of environmental health in children's long-term learning.

Variable	Coefficient (B)	Standard Error	p
Lead Poisoning	0.556	0.264	0.04
Household English	0.005	0.003	0.089
Intercept	0.703	0.029	< .001
Model Results			
$R^2 = .195$			
Adj. $R^2 = .163$			
$F(2,49) = 5.95$			
$p = .005$			

Table 3: Multivariate Regression, Lead Poisoning and Substandard ELA Proficiency, Controlling for Household English Level (n = 52).

Similarly, rent burden was added as a control to assess whether lead poisoning would remain a significant predictor of substandard ELA proficiency. Table 4 shows that this model is still significant, $F(2, 49) = 4.25$, $p = .009$, although it explained slightly less variation in substandard ELA proficiency (Adjusted $R^2 = .161$). A one percent increase in lead poisoning was associated with a .517-percentage-point increase in substandard ELA proficiency, albeit at a nonsignificant level ($p = .06$). In this model, neither household English ($p = 0.09$) nor rent burden ($p = 0.35$) were significant predictors of substandard ELA proficiency.

Variable	Coefficient (B)	Standard Error	p
Lead Poisoning	0.517	0.268	0.06
Household English	0.004	0.002	0.09
Rent Burden	0.096	0.102	0.35
Intercept	0.659	0.054	< .001
Model Results			
$R^2 = .209$			
Adj. $R^2 = .161$			
$F(2,49) = 4.25$			
$p = .009$			

Table 4: Multivariate Regression, Lead Poisoning and Substandard ELA Proficiency, Controlling for Household English Level and Rent Burden (n = 52).

Discussion

This study found a modest positive association between lead poisoning and substandard ELA proficiency at the neighborhood level in Syracuse, suggesting that as average lead poisoning rates increase, so too do average rates of substandard ELA proficiency. Lead poisoning remained a significant predictor of third-grade ELA proficiency after accounting for household English proficiency. The persistence of the association at the neighborhood level is consistent with prior research documenting neuropsychological effects of lead exposure. These effects include deficits in language development [13] and memory [14], both of which plausibly impact how well a child not only develops their language skills but also how they perform on standardized assessments. At the census tract level, lead poisoning rates demonstrated a stronger statistical association with substandard ELA proficiency than household English proficiency. Rent burden was not a significant predictor, suggesting that a family's disposable income after paying for housing did not substantially influence the child's proficiency on standardized ELA assessments. However, lead poisoning remained marginally significant after accounting for rent burden, consistent with Strayhorn and Strayhorn's 2012 findings [8]. While this study utilized a methodology similar to what Strayhorn and Strayhorn used previously, our investigation differs in a few key areas. They used the county as the level of analysis and found significant

associations between blood lead levels and academic achievement at the state-wide level. Our research, however, applied the same methodology to a neighborhood basis by using the census tract as the level of analysis. Given the relatively low R2, the findings of this study are overall not extremely generalizable.

Similarly, this study accounts for the possibility of variation between school districts by exclusively focusing on children enrolled in the Syracuse City School District (SCSD). These findings reinforce prior research concluding that exposure to lead is an adverse childhood experience and social determinant of health. A major barrier in determining accurate lead poisoning rates is the challenge of ensuring that all children have received the mandated testing. As such, the data used in this study may undercount the true number of children with lead poisoning in Syracuse. Future research could also consider how exposure to lead in drinking water affects ELA performance, and subsequently whether lead in the water or in paint is a more common risk of exposure. Similarly, future research may also incorporate racial demographic data. Previous research has established that African American children are significantly more likely to be exposed to lead hazards than their peers [15]. Accounting for race may clarify whether the association between lead poisoning and substandard ELA proficiency intensifies when racial disparities are considered. Such findings would further assist policy makers and community-based organizations in identifying the highest risk households and more effectively target interventions.

Nationally, there has been an increasing focus on the interplay between housing and education. Following on the success of the Harlem Children's Zone, the U.S. Department of Housing and Urban Development (HUD) instituted the Choice Neighborhoods program, focusing on improving housing quality for youth. At the same time, the U.S. Department of Education (DOE) has launched the Promise Neighborhoods program to focus on schools. There has been considerable emphasis on deploying these two grant programs in tandem to tie the funding together. The findings of this study reinforce the connectedness of housing and schooling and suggest that success for one is likely success for the other. Therefore, both housing and lead poisoning are critical elements of a child's upward mobility – improving children's health starts at home.

These findings also underscore the need for early warning systems. Prior research suggests that by the time elevated blood lead levels are detected, neurological impacts may have already occurred. Programs focusing on maternal health and familial education would pre-emptively mitigate the risk associated with lead exposure. Neighborhood-level data may inform community organizations as to which families may be in need of early intervention. Outreach could take the form of working with doulas and other trusted groups locally. Consistent with prior research, enriching early childhood environments have been shown to partially mitigate the cognitive and neurological effects associated with lead exposure [16]. In this context, book distribution programs in highly affected neighborhoods may promote early literacy while also helping to buffer learning disruptions associated with lead exposure.

Conclusion

This study was designed to examine the association between childhood lead poisoning and third-grade ELA proficiency at the neighborhood level in Syracuse. Unlike prior research, this study adopted a more granular unit of analysis and held school district characteristics constant. Findings indicated that lead exposure was modestly yet consistently associated with substandard ELA proficiency, a relationship persisting after controlling for household English proficiency. Rent burden was not a significant predictor of third-grade ELA proficiency.

By extending prior state-wide analyses to the neighborhood level, this study contributes to the literature by highlighting neighborhood variation in educational outcomes associated with environmental health risks. The findings further reinforce existing evidence suggesting that lead exposure is a social determinant of both health and education. Effective policies aimed at preventing lead poisoning would target early identification of young children and infants in high-risk neighborhoods and provide targeted public health interventions, such as book distributions and familial education.

Certain limitations should be noted. Due to incomplete testing, this study may undercount the true number of children experiencing lead poisoning in Syracuse. This study also does not account for potential variation within different neighborhoods. In the future, research may wish to differentiate between sources of lead exposure, such as drinking water or paint, incorporate racial and demographic variables, or analyze variation within neighborhoods.

Because this study relies on aggregate census tract data, the findings should not be interpreted as demonstrating that individual children with elevated blood lead levels perform worse on ELA assessments. Rather, the results identify neighborhood-level associations that warrant further investigation using individual-level longitudinal data. The findings, therefore, are subject to the risk of ecological fallacy, in which relationships at the group level may not remain consistent at the individual level. Similarly, the study uses a small number of census tracts (n = 52), which reinforces the fact that this study ought to be viewed as a high-level neighborhood analysis. Neighborhood-level lead exposure remains a persistent and preventable environmental risk factor associated with educational disparities. Therefore, addressing environmental hazards at the neighborhood level is vital for

improving public health and educational outcomes.

Acknowledgements

The authors thank the Literacy Coalition of Onondaga County, Lead Safe CNY Coalition, and Onondaga County – all of whom provided data used in this study.

Ethical Guidelines

IRB approval was granted for this study on September 21st, 2023 by the Institutional Review Board of LeMoyne College, under application number IRB2023-20A. This study uses administrative records and does not involve study on live human subjects.

Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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