Elevated Blood Lead Levels in Buncombe County Children

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Elevated Blood Lead Levels in Buncombe County Children: Implications of Lowering the North Carolina Intervention Level to the Centers for Disease Control and Prevention Blood Lead Reference Value

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Abstract **Public health interventions in North Carolina were implemented only for children with blood lead levels (BLLs) ≥10 µg/dL until the end of the year in 2017, although the Centers for Disease Control and Prevention (CDC) established 5 µg/dL as a revised reference value for identifying children with elevated BLLs in 2012. This study quantified and characterized the children with elevated BLLs in Buncombe County, North Carolina. A review of case reports of Buncombe County children was conducted through the North Carolina Lead Surveillance System online database. In all, 23 children had confirmed elevated BLLs (≥10 µg/dL) from 2005–2015, while 146 children had BLLs within 5 to <10 µg/dL from 2012–2015. Most of the identified children (62%) lived in Asheville and were 1–2 years old (65%). A significant number of children will be aided and prevented from further lead exposure since North Carolina has lowered the BLL intervention standard to the CDC reference value in 2012. The need for additional staffing at local health departments has been identified to adapt to such change.**

Introduction

Lead is among the most common environmental pollutants, and was used in gasoline, water pipes, and lead-based paint, which is the most significant source of lead exposure today in the U.S. (Anna, 2011). Although fatalities due to lead poisoning are rare in modern times, the risk of elevated blood lead levels (BLLs) and the adverse cognitive effects in children due to these exposures is still present (American Academy of Pediatrics, 2005). Children and infants are more vulnerable to lead poisoning due to the immaturity of their organ systems, growing bodies, high gastrointestinal absorption, and frequent hand-to-mouth habits (Cunningham, 2012). As a result of the increased susceptibility of younger populations, impairment in child development occurs and affects cognitive, behavioral, motor, and physical abilities (Binns, Campbell, & Brown, 2007). High BLLs in children have been shown to be associated with decreased IQ (Binns et al., 2007; Lanphear et al., 2005).

Knowledge of potential lead sources is crucial in determining high-risk populations. The three main sources of lead exposure in children in the U.S. are deteriorating lead-based paint, lead-contaminated dust, and lead-contaminated soil (Binns et al., 2007). Most homes built before 1960 and a few built before 1979 were painted with lead-based paint (Anna, 2011). Moreover, higher rates of lead poisoning were found in geographic areas with higher poverty and/or that have larger minority populations.

When investigating North Carolina, eastern counties that have children with high BLLs were also high-poverty areas with large minority populations (Hanchette, 2008). Many other high-poverty areas in the state, however, were not found to have elevated BLLs in children, indicating that there might be other explanations for higher lead exposures (Hanchette, 2008). Strategies for locating high-risk areas for childhood lead poisoning include selection based on GIS and narrowing down land parcels and neighborhoods based on poverty data and the year homes were constructed (Wilmott, 2009). Such strategies can eventually aide in the risk identification process for health departments and pediatricians (Wilmott, 2009). Considering these factors, lead toxicity in children typically comes from two groups: children living in impoverished conditions and aging homes with poor maintenance, and children from middle- and upper-class families that renovate aging homes without proper anti-contamination measures (Lanphear, 2005).

While the problem has lessened in recent decades, the issue has not vanished as children continue to be exposed to sources of lead. The most recent public health issue related to lead exposure was the contamination of the water supply in Flint, Michigan, exposing thousands of residents and increasing concerns of families for the safety of their children (McLaughlin & Shoichet, 2016). Moreover, recent research showed that BLLs <10 µg/dL still have effects on childhood mental and physical development (Binns et al., 2007). In response to this growing evidence, the Advisory Committee on Childhood Lead Poisoning, in conjunction with the Centers for Disease Control and Prevention (CDC), is currently recommending that the level of lead exposure that is to be deemed a risk for children be reduced from the previous 10 µg/dL to 5 µg/dL (Cunningham, 2012). There still exists the consistent need for the promotion and funding of research to further understand the health effects of blood lead levels <10 µg/dL (Binns et al., 2007).

Until the end of the year 2017, North Carolina Department of Health and Human Services (NC DHSS) considered an "elevated blood lead level" confirmed when a BLL was ≥10 µg/dL for two consecutive tests conducted within 6 months (NC DHSS, 1999). BLLs were tested through capillary (i.e., finger prick) or venous blood collection. The specific method of blood collection used, however, was not always indicated in the case records. Once these conditions were met, the local health department advised the child's guardian and the managing agent of their residence (if applicable) in writing on how to identify potential lead hazards and how to remediate any issues. An investigation from the health department could have been offered at this time, but was not required. If BLLs were consistently >20 µg/dL, however, an investigation became a requirement, as well as remediation. Such interventions can benefit the affected children by preventing further exposure to lead sources.

In 2012, CDC recommended that health departments decrease their intervention level for blood lead from 10 µg/dL to 5 µg/dL. Until the end of the year 2017, the state of North Carolina did not require adaptation to this change, but recommended that children with BLLs >5 µg/dL receive follow-up testing (Norman & Turner, 2012). Thus, since 2012, there are a number of children in Buncombe County with BLLs of 5 to <10 µg/dL who might have benefitted from this change but were excluded from repeat screenings and interventions because North Carolina did not adopt the CDC reference value immediately. North Carolina passed a new state budget in 2017 that allowed for lowering the blood lead intervention level to 5 µg/dL, triggering the investigation and remediation components of the amended state law by January 1, 2018 (Norman, 2017). The investigation and remediation components are offered and not required for BLLs of 5–9 µg/dL. BLLs of 10 µg/dL or above will require both investigation and remediation. The purpose of this study was to quantify and characterize the children with elevated BLLs (>10 µg/dL) and those with BLLs of 5 to <10 µg/dL in Buncombe County prior to the change in the North Carolina state law.

Methods

Study Participants

Participants in this study were children in Buncombe County, North Carolina, who had existing lead reports available on their cases from 2005–2015. These reports were created in local and/or state records once a child has a detected BLL, and potentially becomes a part of the investigation process depending on several factors (e.g., initial blood lead level, confirmation test results, guardian's wishes). Buncombe County is located in the western part of the state in the mountainous region. Based on the 2010 census, the population was documented as 238,318 residents, with an estimated 22% of residents being children <18 years old (U.S. Census Bureau, *American FactFinder,* n.d.). Residential locations of children included in the study were Alexander, Arden, Asheville, Barnardsville, Bent Creek, Biltmore Forest, Black Mountain, Candler, Fairview, Leicester, Montreat, Ridgecrest, Royal Pines, Sandy Mush, Swannanoa, Weaverville, and Woodfin.

Data Collection

We collected secondary data on Buncombe County children by reviewing archived lead reports through the Buncombe County Department of Health, the North Carolina Lead Surveillance System (NC LEAD) online database, geographical maps, and other relevant documents from the North Carolina Childhood Lead Poisoning Prevention Program. With the goal of providing direct access to clinical and environmental data related to childhood lead exposure, NC LEAD is a module of the North Carolina Electronic Disease Surveillance System, a component of the web-based surveillance and reporting systems initiative by CDC (NC DHHS, 2017).

The data pool includes all children tested with at least 1µg/dL of lead detected in the blood. Information collected included demographic data (i.e., age, sex, location of neighborhood residence) and BLLs of these children. Children were categorized based on BLLs (≥10 µg/dL; 5 to <10 µg/dL). Cases with confirmed BLLs ≥10 µg/dL from 2005–2015 were easily identified from the data pool. Due to the tedious process of manually reviewing individual case reports in the NC LEAD database to identify children with BLLs of 5 to <10 µg/dL, however, only records from June 2012 (when CDC changed the blood lead reference value) to October 2015 were reviewed, as the software program we used did not allow data search by "blood lead level" as a parameter but instead could only segregate cases with confirmed BLLs ≥10 µg/dL from the data pool. Data obtained through manual review of individual case reports were manually entered into spreadsheets. Personal identifiers (i.e., name) that could link information to the participants were removed. Permission under HIPAA rules and approval from the East Carolina University Institutional Review Board (approval # UMCIRB 15-00462) were obtained prior to data collection.

Data Analysis

Frequencies and percentages for categorical measures were summarized, while means and standard deviations for continuous measures were determined. Microsoft Excel was used to create worksheets for tabulation and further analysis. Analysis of variance (ANOVA) was conducted to compare mean BLLs by age, sex, and residence location using the online VassarStats statistical software with $p < .05$ considered statistically significant.

Results

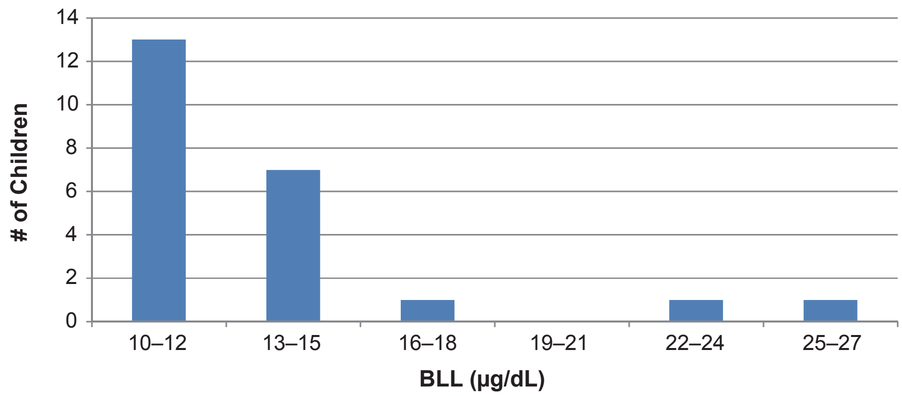
Children With Elevated BLLs (≥10 µg/dL) From 2005–2015

We identified 23 children having confirmed elevated BLLs (≥10 µg/dL) from the 2005–2015 database. When confirming an elevated BLL, the lower of the two tests that show BLLs ≥10 µg/dL was designated as the official BLL for the course of the investigation. The average BLL recorded for these children was 14.1 µg/dL, ranging from 10–28 µg/dL. The majority (56.5%, $n = 13$) had BLLs from 10–12 µg/dL, while 30.4% ($n = 7$) had BLLs from 13–15 µg/dL (Figure 1). More than half (56.5%, $n = 13$) of the children were male (Table 1). The average age of children affected was 19.9 months old. More than half (56.5%) of the children were in the age range of 12–23 months, with an average BLL of 13.92 ± 5.31 µg/dL (Table 1). The majority of these children (52.2%) were located within the city limits of Asheville, followed by Black Mountain (17.5%), and Arden (8.8%). Neighborhood locations categorized under "other" included Candler, Leicester, Swannanoa, Weaverville, and one unrecorded, with each location having one child with confirmed elevated BLLs (Table 1). No significant differences were found in average BLLs by sex ($p = .44$), age ($p = .23$), or location ($p = .54$).

While North Carolina law requires local environmental health departments to follow up on these cases, many have not been able to or have not yet reached conclusion. Although not documented in the database, the reasons that these cases were closed upon attempted follow-up included but were not limited to 1) BLL was within acceptable levels during follow-up blood test, 2) family moved out of the county's jurisdiction, 3) children aged out of 6-year-old surveillance age, or 4) parent or guardian refused service from the health department. In all, 13 of these cases were closed without conclusion. As of December 2015, four cases were still ongoing due process, and therefore have not yet reached the investigation or communication stage with parent or guardian. Three cases were caused by parental occupation wherein parents were exposed to lead at work and then brought home the lead contaminants, resulting in exposure of the child. One case was found to be due to exposure to peeling lead paint in the area around the home (i.e., play area located immediately outside of the home), while another case was found to be due to peeling paint within the home.

FIGURE **1**

Distribution of Children With Elevated Blood Lead Levels (BLLs) (≥10 µg/dL) in Buncombe County, North Carolina, by BLL Range, 2005–2015 (*n* = 23)



Children With BLLs of 5 to <10 µg/dL From 2012–2015

We manually reviewed a total of 6,000 NC LEAD records of children with BLLs >1 µg/dL from June 2012–October 2015 to identify those with BLLs from 5 to <10 µg/dL. Of these reviewed records, 146 (2.4%) had BLLs of 5 to <10 µg/dL, which reflects the number of children who would have received government intervention from the environmental health department from June 2012–October 2015 if the new CDC blood lead reference value had been immediately adapted.

Out of these 146 children, 63.7% ($n = 93$) were found to be within the city limits of Asheville (Table 2). Specifically, 9 (6.1%) resided in Weaverville, 7 (4.8%) in Black Mountain, 6 (4.1%) in the town of Fairview, and 12 (8.2%) children in "other" residence locations were spread among the small communities of Alexander, Bent Creek, Fletcher, Montreat, Ridgecrest, and Royal Pines (Table 2). Moreover, out of the children with BLLs of 5 to <10 µg/dL, 61% ($n = 89$) were male. The average age of these children was 17.00 ± 7.26 months, or about 1–2 years of age, and their average blood lead level was 5.91 ± 1.27 µg/dL.

Table 3 shows the number, average age, and average BLL of these 146 children by year from 2012–2015. Only the last 6 months of 2012 were studied due to CDC changing their recommended reference value on June 2012. The year with the highest number of children with BLLs of ≥5 to <10 µg/dL ($n = 51$) was 2013, with an average of 4.3 children per month. There was a decreasing trend yearly in the average age of children during this period, while the yearly average BLLs were steady.

Considering the 23 children with BLLs of >10 µg/dL from 2005–2015 and the 146 children with BLLs of ≥5 to <10 µg/dL from 2012–2015, 169 children would have been the total number of children investigated from 2005–2015 as a result of CDC lowering the reference value for identifying children with elevated BLLs for government intervention. The average age of these 169 children was 17.4 ± 7.8 months. Table 4 shows the demographic distribution of these children by age, sex, and residence location. The majority of the children (64.5%, $n = 109$) were in the age range of 1–2 years and were male (59.8%, $n = 101$). A majority (62.1%, $n = 105$) were found to be within the city limits of Asheville, followed by 6.5% ($n = 11$) in Black Mountain, and 5.9% ($n = 10$) in Weaverville. The cities with the least number of children were Alexander, Bent Creek, Candler, Marshall, and Ridgecrest, with one child (0.6%) in each city.

Discussion

This study showed that most of the children with elevated BLLs were within the city limits of Asheville. This finding could be attributed to the presence of older homes and apartments within the city limits as a risk factor to lead exposure, as several studies have shown associations between older homes and elevated BLLs (Binns et al., 2007; Kim, Staley, Curtis, & Buchanan, 2002; Whitehead et al., 2014). According to Sperling's Best Places (2015), the median age of homes in Asheville is 42 years old, which is 5 years older than the median for the U.S. Furthermore, Hanchette (2008) stated that houses built pre-1950 are concentrated in cities and towns, partially

TABLE **1**

Average Blood Lead Levels (BLLs) of Children With Confirmed Elevated BLLs (≥10 µg/dL) in Buncombe County, North Carolina, by Age, Sex, and Residence Location, 2005–2015 (*n* = 23)

Characteristic	# (%)	Average BLL	*p*-Value
Sex			.44
Male	13 (56.5)	13.07 ± 3.64	
Female	10 (43.5)	19.70 ± 9.83	
Age			.23
<12 months	1 (4.3)	12.58 ± 0.00	
12–23 months	13 (56.5)	13.92 ± 5.31	
24–59 months	9 (39.1)	12.56 ± 2.19	
Location			.54
Asheville	12 (52.2)	12.58 ± 4.66	
Black Mountain	4 (17.5)	14.00 ± 1.41	
Arden	2 (8.8)	14.00 ± 0.00	
Other	5 (21.7)	14.33 ± 5.13	

TABLE **2**

Number of Children With Blood Lead Levels ≥5 to <10 µg/dL by Residence Location in Buncombe County, North Carolina, 2013–2015 (*N* = 146)

Residence Location	#	%
Asheville	93	63.7
Weaverville	9	6.1
Black Mountain	7	4.8
Fairview	6	4.1
Leicester	5	3.4
Barnardsville	4	2.7
Swannanoa	4	2.7
Arden	3	2.0
Woodfin	3	2.0
Other	12	8.2

explaining the pattern of lead poisoning in these areas with older homes.

Binns and coauthors (2007) reported that among houses built prior to 1940, 68% contain lead hazards; 43% of houses built between 1940–1959 and 8% of houses built between 1960–1977, respectively, contain lead hazards. Moreover, a study by Whitehead and coauthors (2014) found that dust in older homes contained higher levels of lead and other persistent chemicals compared with dust in newer homes.

It must be recognized that at-risk populations not only include children from low-income and/or minority families in older homes but also children from many middle-class families who are moving into historic neighborhoods with older houses that underwent subsequent renovation, including those in ZIP codes considered to be at high risk (Crotty & Eldridge, 2013). Specifically, the Environmental Health Section of the North Carolina Division of Public Health provides a list of all North Carolina ZIP codes in which all children should undergo blood lead screening due to high-risk lead exposure (NC DHHS, 2016).

North Carolina, specifically in Buncombe County, has a need for improved prevention strategies and outreach for lead exposure prevention among children from families of varying socioeconomic status. Another factor to investigate is the role of day care centers in children's lead exposure, as most of these centers are located within city limits. Risk factors in day care centers are similar to those found in residential properties, including lead-based paint as a potential source in older facilities (Button, 2008). A Cincinnati study by Button found that lead concentrations in the soil within 1.5 m from the exterior walls of day care centers were significantly higher than concentrations found in soil from the remainder of the playground. The same study also found higher lead concentrations in soil at day care centers located closer to interstate highways, which usually are within city limits.

Other possible sources of lead exposure for children located within city limits might also include older schools, libraries, and other building structures, and warrant further investigation. It must be noted, however, that based on 2014 data, 35% of Buncombe County's residents were within Asheville city limits (U.S. Census Bureau, *QuickFacts*, n.d.), which might contribute to the higher proportion of children with elevated BLLs in Asheville.

The age of children with elevated BLLs in Buncombe County was found to be in the range of 1–2 years old, which agrees with the general understanding that children of early toddling age are at the highest risk of elevated BLLs. Taking this age range as a definitive representation of the age when children are most likely to ingest lead, however, is discouraged because most of the blood lead levels were obtained at milestone birthdays such as 12 and 24 months. BLLs were not monitored continuously in between these milestone ages and, therefore, do not necessarily reflect the age when children begin ingesting lead.

One important finding in this study demonstrates the striking difference between the number of children who benefited from government interventions due to having BLLs ≥10 µg/dL and the number of children who were in the gray area of having BLLs at or above the CDC recommendation of 5 µg/dL for government intervention, but did not reach the previous North Carolina government intervention level of 10 µg/dL. While there were fewer than 10 children each year with BLLs ≥10 µg/dL, there were 30–50 children annually who had BLLs between 5 and <10 µg/dL. While we did not have complete data from 2015 when this paper was written, the recorded number of children in the range of 5 to <10 µg/dL for 2015 was 33. These data demonstrate that there was a need for more

TABLE 3

Number, Average Age, and Average Blood Lead Level (BLL) of Children With BLLs of ≥5 to <10 µg/dL in Buncombe County, North Carolina, by Year, 2012–2015 (*N* = 146)

Characteristic	2012[a]	2013	2014	2015[b]
Number of children per year	29	51	33	33
Number of children per month	4.1	4.3	2.8	3.3
Age of children (months)	18.1 ± 6.7	17.5 ± 7.6	16.9 ± 7.1	16.7 ± 6.1
BLL of children (µg/dL)	6.2 ± 1.4	5.7 ± 1.1	5.8 ± 1.2	6.1 ± 1.4

[a]June–December 2012.
[b]January–October 2015.

TABLE 4

Distribution of Children With Blood Lead Levels Above the Centers for Disease Control and Prevention Recommended Reference Value by Age, Sex, and Residence Location in Buncombe County, North Carolina, 2005–2015 (*N* = 169)

Characteristic	#	%
Age		
<1 year	7	4.1
1–2 years	109	64.5
3–5 years	53	31.4
>5 years	0	0
Sex		
Male	101	59.8
Female	68	40.2
Residence location		
Asheville	105	62.1
Black Mountain	11	6.5
Weaverville	10	5.9
Fairview	6	3.6
Leicester	6	3.6
Swannanoa	5	3.0
Arden	5	3.0
Barnardsville	4	2.4
Woodfin	3	1.8
Fletcher	3	1.8
Montreat	3	1.8
Royal Pines	2	1.2
Bent Creek	1	0.6
Alexander	1	0.6
Ridgecrest	1	0.6
Candler	1	0.6
Marshall	1	0.6
Unknown	1	0.6

involvement from the local health department with these 33 children.

Before the amended North Carolina state law, these children in the gray area (i.e., children with BLLs between 5 and <10 µg/dL) were not recommended to have follow-up blood work and the health department did not contact the families for additional information. Unless they had guardians who were proactive enough in acquiring more information about the children's current BLLs and researching the implications for themselves, or unless they were fortunate enough to have doctors take notice of these BLLs and review related potential risks and causes, these children could have been exposed to dangerous lead levels with no precautions or interventions.

Several studies have shown that there is no safe BLL in children, and that very low BLLs can negatively affect their behavioral and cognitive functions (i.e., decreased IQ) (Bellinger, 2008; Canfield et al., 2003). Thus, providing interventions to children with BLLs ≥5 µg/dL will prevent further lead exposure and, consequently, reduce both the severity of its health effects and the number of affected children.

It is important to note that local health departments might not have the staff and capability to reach out to children who have BLLs that fall between 5 and <10 µg/dL. In Buncombe County, at the time of writing, the responsible personnel in the local health department had a full workload in addressing a handful of cases that require intervention annually. As North Carolina lowers the intervention standard to the CDC reference value, in order to be capable of efficiently handling 4–10 times the current workload, additional training of other staff members or hiring additional employees would be necessary to meet a workload that involves more repeat lead screenings.

This increased staffing need was recognized by the state when the law was amended (Norman, 2017). Consequently, purchasing additional equipment (i.e., X-ray fluorescence analyzers) required to detect and quantify lead in paint, toys, and furniture would likely need to be considered, especially if more investigations will be conducted. This equipment can be expensive to purchase and maintain, and thus such equipment is not always readily available. Area county departments must often wait until a state regional specialist with access to such equipment can travel to conduct an inspection with the local health department. The lack of resources, combined with a growing demand from the public, would likely result in lengthy wait times before children can be helped. This delayed intervention would only amplify problems for individual children as they risk continued exposure while they wait for assistance.

As North Carolina implements the changes on the BLL standard, related issues on funding, time constraints, and staffing will need to be addressed by health departments. Conducting a cost-benefit analysis regarding the adaptation to the CDC reference value in Buncombe County and other North Carolina counties will be beneficial, but is not within the scope of this study. The state's Childhood Lead Poisoning Prevention Program is currently addressing these issues internally as preparations are being made to expand the program's workload. Changes being implemented include increased staffing of environmental health regional specialists (Norman, 2017).

Strengths and Limitations

Findings of this study shed some light on the political, financial, and other implications of lowering the BLL for intervention to the recommended CDC reference value.

This study might be extended to other counties in North Carolina to further determine other factors that can affect the implementation of the change in intervention level. While Buncombe County is an advantageous county to study due to its large size and mix of rural and urban communities, a larger sample would provide a better understanding of children who will benefit from this policy change, as well as the needed resources to implement the policy change. If all 100 North Carolina counties could not be studied due to financial and other constraints, the selection of North Carolina counties to study can be based on certain parameters such rural versus urban, high versus low population, or by regions (i.e., Eastern, Western, and Piedmont).

Several challenges were encountered in collecting data for this study. As the program was in need of updating, the NC LEAD online database offered no simple way to sort entries by BLL or date of screening. The only item available to use to narrow down results was the ability to look at only Buncombe County data instead of the whole state. Therefore, it was necessary to manually collect data by starting at the most recent children tested to have at least 1 µg/dL of BLL, and scroll chronologically to open each child's file one at a time. When this study was conducted, the program was tailored more for employees who know the exact name or case ID of the child being investigated. It is hoped that with the advancement of the North Carolina Lead Program, the online database will be improved accordingly to become more efficient for government employees in conducting searches and analyses.

Conclusion

This study investigated the number of children in Buncombe County who had confirmed elevated BLLs ($\geq$10 µg/dL) in the last 10 years, and children who had BLLs from 5 to <10 µg/dL since mid-2012. The latter data set was studied to determine the implications of CDC lowering their recommended reference value for BLL for government intervention from 10 µg/dL to 5 µg/dL as applied to North Carolina, specifically to Buncombe County. Toddlers living within the city limits of Asheville were more likely to have the highest risk of lead exposure than children of other ages and residential locations.

A significant number of children will benefit from governmental interventions in preventing further lead exposure as North Carolina lowers the intervention standards to include children with BLLs of 5 µg/dL or more. This study confirmed the need for policy change in North Carolina to stay in step with the CDC recommendation by revising the standard for government intervention and supports North Carolina's recent policy change. Prior to the change in North Carolina standards, only a small portion of children were aided through local health departments compared with a higher number of children who could have been assisted if standards had been more quickly adjusted to the CDC recommendation.

The recent adaption of North Carolina to the CDC recommendation will be beneficial to a significant number of children affected by lead exposure. A change of this magnitude, however, will be feasible only if there is also an increase in staffing in local health departments, which entails more financial resources, as already recognized by the state. The results of this study indicate that researchers and policy makers can work together cooperatively to help to protect public health.

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