Illinois Morbidity and Mortality Bulletin

IDPH
ILLINOIS DEPARTMENT OF PUBLIC HEALTH

Message from Director Shah

Welcome to the seventh issue of the Illinois Morbidity and Mortality Bulletin (IMMB), an IDPH publication created to present topics of interest to public health communities and professionals in Illinois through scientific analysis and interpretation of data.

In this issue, Kelly Walblay, Livia Navon, and Jennifer Layden describe implementation of the Illinois Zika surveillance system and summarize Illinois surveillance data from January 2016 through December 2017.

In the second article, Emily Szwiec, Kimberly Weems, Linda Forst, Lee Friedman, and Tiefu Shen examine distributions and trends in elevated blood lead levels in adults for Illinois from 2005 through 2017.

We encourage manuscript contributions from public health professionals at the state and local levels, as well as those in hospitals and academic institutions. Please send your manuscripts to IMMB's editor, Tiefu Shen, M.D., Ph.D. at Tiefu.Shen@illinois.gov (217.785.1873)

Nirav D. Shah, M.D., J.D.
Director
Illinois Department of Public Health

A Comprehensive Summary of Zika Surveillance Data, Illinois, January 2016-December 2017

In 2015, Zika virus began spreading rapidly across Central and South America. In 2016, as the association of Zika infection and adverse pregnancy outcomes became apparent, the rapid spread of the disease was declared a public health emergency. This report describes the implementation of the Illinois Zika surveillance system and summarizes Illinois Zika surveillance data from 2016–2017. Zika laboratory results are reportable to the Illinois Department of Public Health (IDPH). Due to the complexity of determining the correct Zika test to perform, IDPH requested both positive and negative lab results to ensure appropriate testing was ordered. In this report, Zika surveillance data from January 2016–December 2017 were utilized to calculate .... read more

Distributions and Trends in Elevated Blood Lead Levels in Adults – Illinois, 2005-2017

Lead is an agent known to be toxic to humans that can adversely affects multiple organ systems in the human body. Lead exposures can be estimated through blood lead levels. In efforts to monitor the number of individuals in Illinois who are exposed to lead and to reduce the burden associated with lead exposure, the Illinois Adult Blood Lead Registry, in the Division of Epidemiologic Studies, Illinois Department of Public Health, tracks cases of elevated blood lead $\geq 10\mu g/dL$ as mandated by the Illinois Health and Hazardous Substances Registry Act [410 ILCS 525]. The objective of this report is to analyze the trends in the .... read more

Kelly Walblay, MPH[1,2]
Livia Navon, MS[1]
Jennifer Layden, MD, PhD[1]

Abstract

In 2015, Zika virus began spreading rapidly across Central and South America. In 2016, as the association of Zika infection and adverse pregnancy outcomes became apparent, the rapid spread of the disease was declared a public health emergency. This report describes the implementation of the Illinois Zika surveillance system and summarizes Illinois Zika surveillance data from 2016– 2017. Zika laboratory results are reportable to the Illinois Department of Public Health (IDPH). Due to the complexity of determining the correct Zika test to perform, IDPH requested both positive and negative lab results to ensure appropriate testing was ordered. In this report, Zika surveillance data from January 2016–December 2017 were utilized to calculate descriptive statistics and positivity rates by demographics, risk factor, pregnancy status, and presence of symptoms. IDPH received test results for 6,998 individuals with 125 cases meeting the Zika case definition. The majority of tested individuals (84.2%) and cases (64.8%) were female, although males had a higher positivity rate (4.0% vs. 1.4%). Although a high proportion of tested individuals were asymptomatic pregnant women (56.2%), symptomatic (92.0%) and non-pregnant (88.0%) individuals accounted for the majority of cases. Almost all cases were infected during travel to an area with local Zika transmission (96.8%). Birth outcomes for pregnant cases (n=14) included three congenital Zika infections, where one infant was symptomatic at birth. The number of Zika cases in Illinois peaked in July 2016 followed by a sharp decline after August 2016. Lessons learned from rapid implementation of Zika surveillance can be utilized to improve surveillance for new emerging infectious diseases in Illinois.

Introduction

Zika virus (Zika) is a flavivirus primarily transmitted by the *Aedes aegypti* mosquito. Zika can also be transmitted vertically from mother-to-child, sexually, and through blood transfusion.[1] In 2015, local mosquito-borne transmission of Zika was identified in Brazil and the virus began spreading rapidly across the Americas.[2] In 2016, U.S. states and the District of Columbia reported 5,168 non-congenital Zika cases.[3] Although the majority of Zika infections in humans are asymptomatic, symptoms can include self-limiting rash, fever, conjunctivitis, and arthralgia.[1]

In early 2016, the World Health Organization declared Zika a public health emergency due to its linkage with birth defects, including microcephaly and other neurological sequelae.[1-2,4-6] Consequentially, the Centers for Disease Control and Prevention (CDC) recommended Zika testing for asymptomatic pregnant women with exposure to Zika-endemic areas (either directly or through a sexual partner who traveled to a Zika-endemic area) because of the risk for congenital disease.[7,8] CDC also recommended testing symptomatic individuals with appropriate travel or sexual exposure.[8] Testing guidelines and recommendations continuously evolved with the epidemic.

Because of the significant public health risk, a Zika surveillance system, including strengthening laboratory testing capacity, had to be rapidly developed and deployed. The purpose of this report is to describe implementation of the Illinois Zika surveillance system and to summarize Illinois surveillance data during 2016 and 2017.
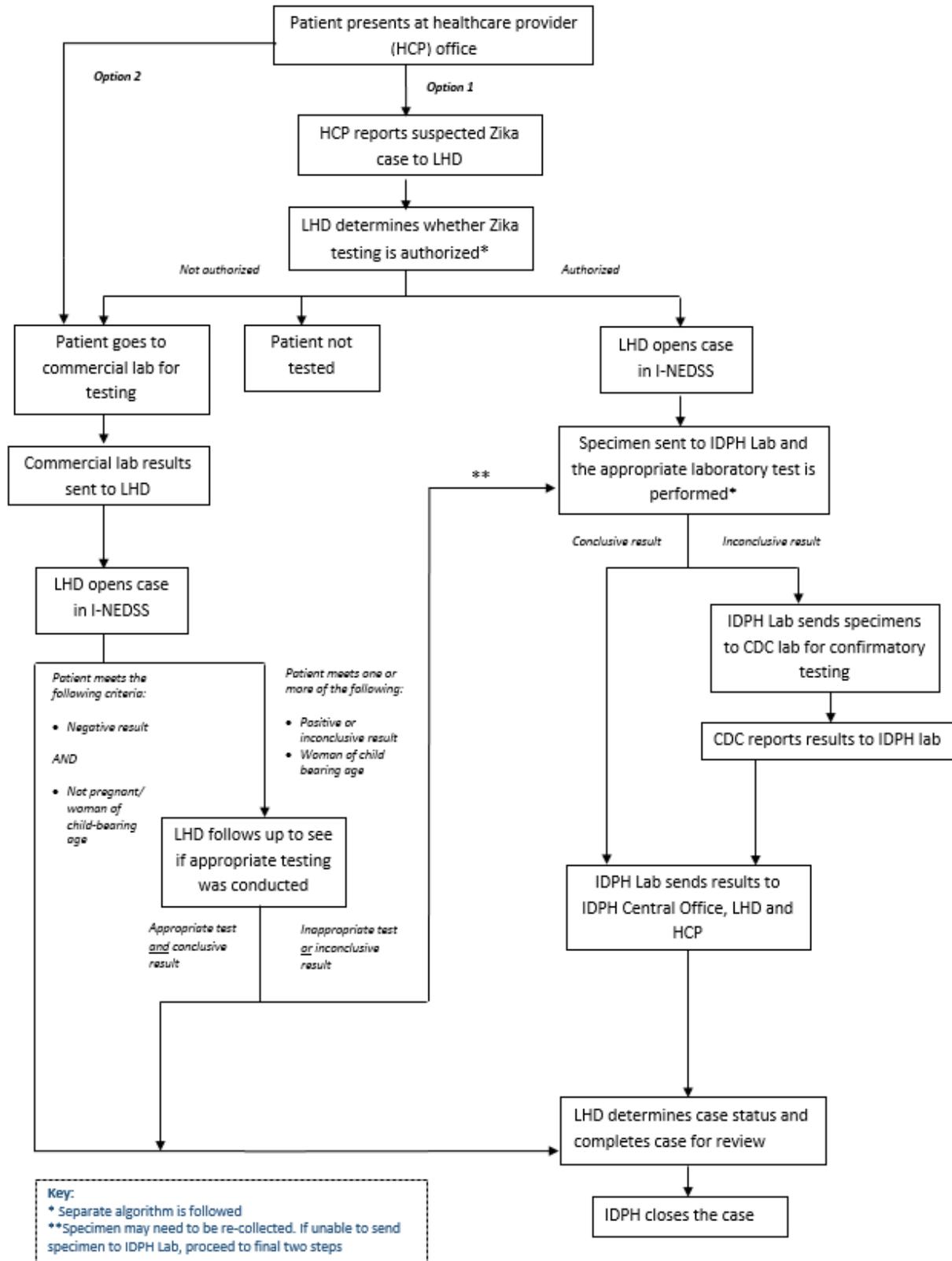
Methods

Illinois Zika Surveillance System
IDPH began Zika surveillance in January 2016 through the use of the Illinois National Electronic Disease Surveillance System (I-NEDSS), a state-wide, web-based application for communicable disease case reporting. A separate Zika module was created in I-NEDSS to collect testing results and other Zika-specific epidemiologic information. The module was deployed in February 2016. Earlier Zika testing data were tracked in Microsoft EXCEL and were entered into I-NEDSS after the module was created. Zika infection is a reportable disease under Illinois Administrative Code Title 77, Chapter 1, Subchapter k, Part 690, Section 690.322 and is required to be reported by health care providers, hospitals, and laboratories. Zika reporting falls under the same reporting code as other arboviral diseases, including but not limited to dengue and chikungunya.

At the start of Illinois Zika surveillance, only CDC laboratories were able to perform Zika testing and all specimens collected in Illinois where shipped to CDC for testing. Beginning in May 2016, IDPH laboratories developed testing capacity and CDC laboratories were only utilized for confirmatory testing for inconclusive test results. Initially, when a suspect case was reported to a local health department (LHD) by a health care provider or hospital, LHD staff would determine if the patient met the criteria for Zika testing and would recommend which test to perform following the current CDC guidelines. This approval process was enacted due to limited laboratory capacity and the complexity of Zika testing which requires the use of different diagnostic tests depending on when a patient was exposed to the virus or onset of symptoms. Once commercial laboratories began conducting Zika testing, individuals could be tested for Zika without health department approval.

Laboratory results from Zika testing, including negative results, were reported to LHDs and captured in I-NEDSS. Negative result reporting is atypical for routine infectious disease surveillance in Illinois and was requested so LHDs could ensure the correct diagnostic test was performed for women of child-bearing age, given the additional risks of Zika infection during pregnancy. The case status of tested individuals is determined following the Council of State and Territorial Epidemiologists Zika case definitions.[9] The Illinois Zika surveillance system is outlined in Figure 1.

Figure 1. Flowchart of the Illinois Zika Surveillance System.

Figure 1. Flowchart of the Illinois Zika Surveillance System.

Key:
* Separate algorithm is followed
**Specimen may need to be re-collected. If unable to send specimen to IDPH Lab, proceed to final two steps

Data

Zika data reported to I-NEDSS from January 2016 through December 2017 were utilized in this analysis. In addition to Zika laboratory testing results and specimen collection date, LHDs can enter demographic information, pregnancy status, pregnancy outcome, presence of symptoms, and risk factor information into I-NEDSS. The risk factor variable is classified as "travel" if an individual indicates significant travel or travel to a country with local Zika transmission; "sexual" if the individual reports no travel and a sexual partner with recent travel to a country with local Zika transmission; "congenital" if the individual is a neonate born to a mother with Zika or recent Zika exposure; and "unknown" for any individual that does not meet one of the previously specified criteria.

Data analyses

Descriptive statistics were calculated for all individuals tested and Zika cases. Zika testing positivity rates were examined by demographics, risk factor, pregnancy status, and presence of symptoms. Because individuals may have more than one specimen collected for testing, the earliest specimen collection date was used to calculate dates for the epidemic curve. Chi-squared tests were used to analyze differences in positivity rates between males and females and pregnant women and non-pregnant women, controlling for symptoms (α=0.05). Zika case counts and case rates per 100,000 people were mapped by county using ArcGIS software.[10]

Results

Testing volume and positivity rates

During January 2016–December 2017, 6,998 people were tested for Zika in Illinois and 125 confirmed cases were identified (1.8% positivity rate). The number of individuals tested each month varied with the highest number of specimens collected in February 2016 (n=530), followed by August 2016 (n=473). The positivity rate was highest in January 2016 (21.7%) when Zika testing first began, with a second peak occurring in July 2016 (14.0%) (Figure 2). An increase in testing occurred in late summer of 2016 and a slight increase in testing was seen in January and the summer months of 2017 compared to the rest of that year. After August 2016, there was a sharp decline in the number of confirmed Zika cases and an overall gradual decline in the number of individuals tested after August 2017.

Figure 2. Number of individuals tested and Zika cases by specimen collection date, with percent positivity rate, Illinois, 2016-2017.*
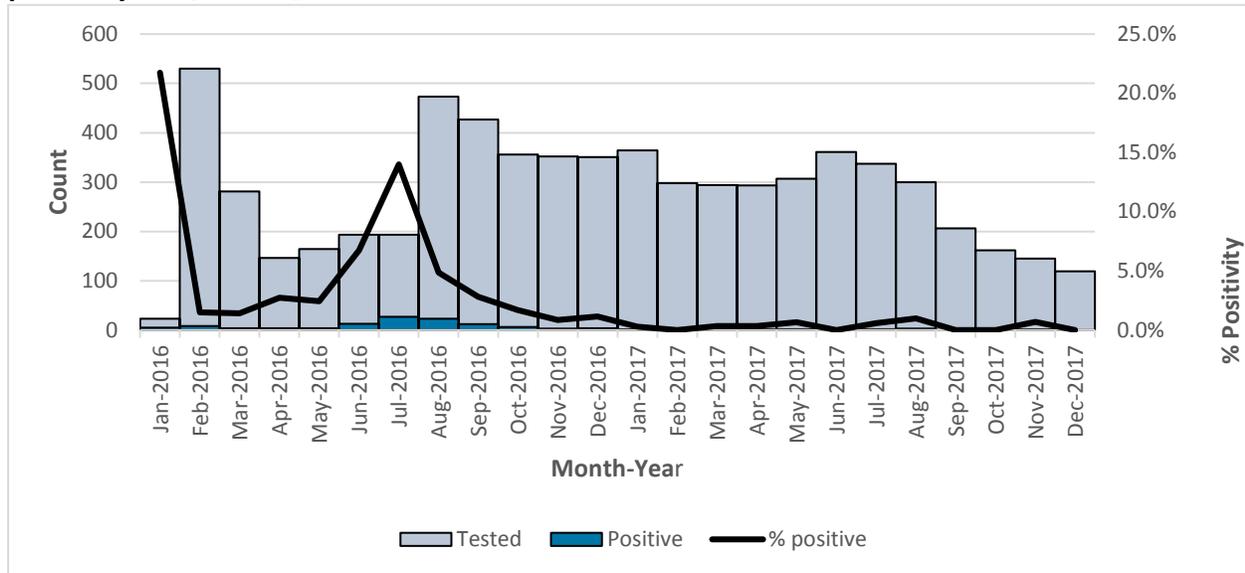
*273 observations were excluded (including 1 case) from the epi curve due to missing specimen collection dates and data entry errors.

Geographic distribution

The distribution of Zika cases across the state showed a clustering in the Northeastern region of Illinois, with most cases occurring in Cook County and Chicago (Figure 3). Although the more populous jurisdictions accounted for the highest number of cases, incidence rates were higher in less populated counties.

Figure 3. Number of Zika cases and incidence rates per 100,000 people by county, Illinois, 2016-2017
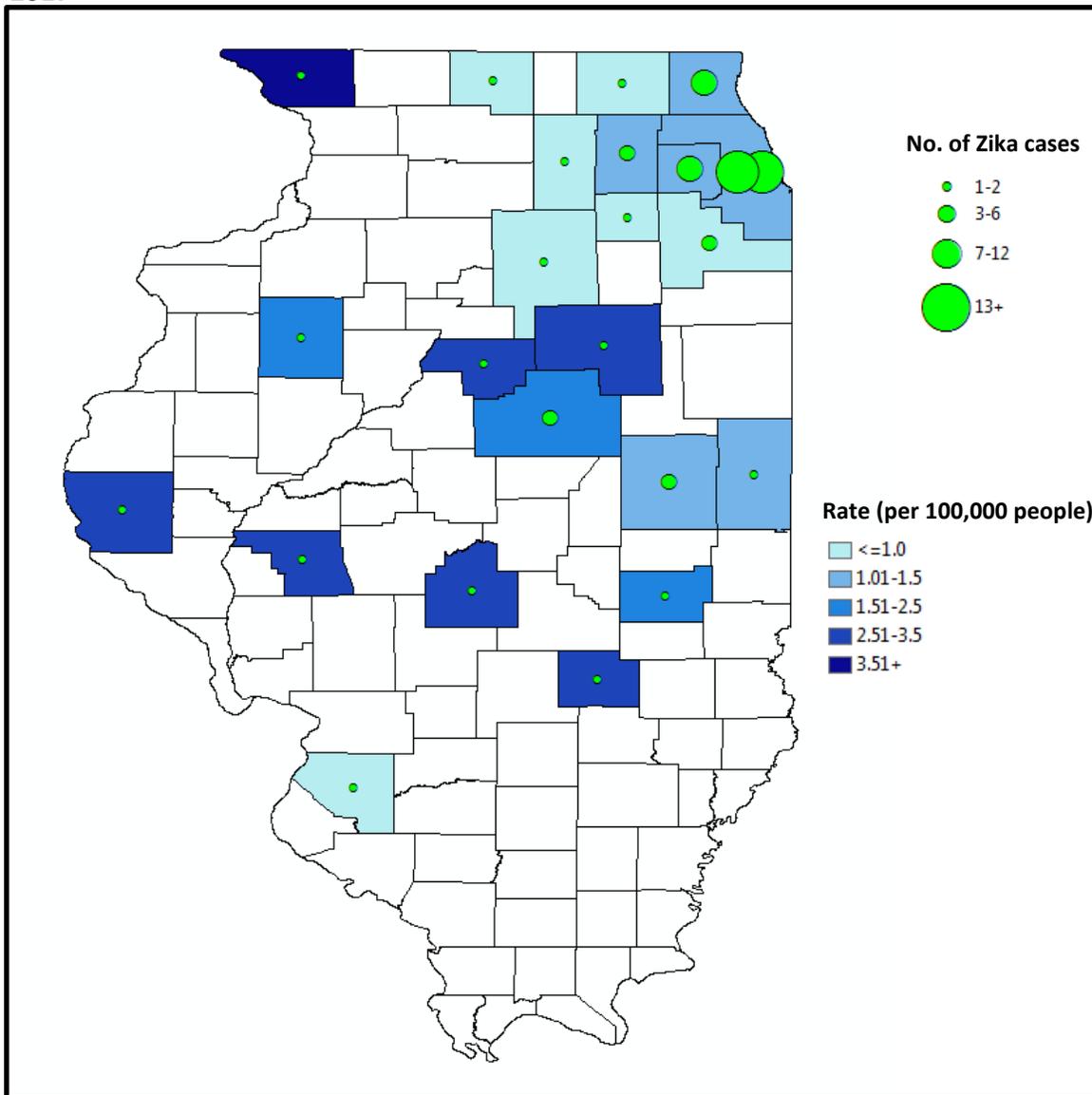
Descriptive statistics

Testing volume and positivity rates differed by sex, age, and symptom status. Although 84.2% of tested individuals were female, males had a higher positivity rate: 4.0% compared to 1.4%. Younger adults, particularly those of childbearing age, accounted for the majority of tested individuals, however, positivity rates were highest among adults aged 50-59 years (14.4%) and ≥60 years (11.2%). The median age for confirmed cases was 31 years (range 0-83 years). Of those tested, 4,161 were pregnant women (59.5%); however, they accounted for only 17.3% of female cases and 11.2% of all cases. By race and ethnicity, 48.0% of confirmed cases were white and 26.4% identified as Hispanic or Latino, though race and ethnicity were unknown for a large proportion of individuals (59.2% and 57.5% respectively). While the majority of tested individuals were asymptomatic (63.8%), nearly all confirmed cases (92.0%) were symptomatic (Table 1).

Table 1. Descriptive statistics of individuals tested and Zika cases with positivity rates, Illinois, 2016-2017.

Variable	Number tested (N=6,998) n (%)	Number of cases (N=125) n (%)	Positivity rate
Sex			
Male	1,093 (15.6%)	44 (35.2%)	4.0%
Female	5,895 (84.2%)	81 (64.8%)	1.4%
Unknown/Missing	10 (0.1%)	0	0.0%
Age (years)[1]			
0-9	112 (1.6%)	4 (3.2%)	3.6%
10-19	207 (3.0%)	10 (8.0%)	4.8%
20-29	2,371 (33.9%)	29 (23.2%)	1.2%
30-39	3,636 (52.0%)	37 (29.6%)	1.0%
40-49	411 (5.9%)	13 (10.4%)	3.2%
50-59	131 (1.9%)	18 (14.4%)	13.7%
≥60	119 (1.7%)	14 (11.2%)	11.8%
Unknown/Missing	9 (0.1%)	0	0.0%
Race			
White	2,237 (32.0%)	60 (48.0%)	2.7%
Black	122 (1.7%)	4 (3.2%)	3.3%
Asian	143 (2.0%)	0	0.0%
Other[2]	352 (5.0%)	9 (7.2%)	2.6%
Unknown/Missing	4,144 (59.2%)	52 (41.6%)	0.9%
Ethnicity			
Hispanic or Latino	1,235 (17.6%)	33 (26.4%)	2.7%
Not Hispanic or Latino	1,739 (24.8%)	39 (31.2%)	2.2%
Unknown/Missing	4,024 (57.5%)	53 (42.4%)	0.8%
Symptomatic			
Yes	1,023 (14.6%)	115 (92.0%)	11.2%
No	4,462 (63.8%)	10 (8.0%)	0.2%
Unknown/Missing	1,513 (21.6%)	0	0.0%
Pregnant[3]			
Yes	4,161 (70.6%)	14 (17.3%)	0.3%
No	659 (11.2%)	66 (81.5%)	10.0%
Unknown	1,074 (18.2%)	1 (1.2%)	0.0%
Risk Factor			
Travel	5,070 (72.4%)	121 (96.8%)	2.4%
Sexual	159 (2.3%)	1 (0.8%)	0.6%
Congenital	70 (1.0%)	3 (2.4%)	4.3%
Unknown/Missing	1,699 (24.3%)	0	0.0%

[1]Two observations dropped due to incorrect age reported (>110 years)

[2] Other includes American Indian/Alaskan, Native Hawaiian or Other, Other, and Two or more

[3]Denominator is females only (n=5,895 for tested individuals and n=81 for cases)

Comparing positivity rates by sex, pregnancy status and presence of symptoms

Males tested for Zika had a significantly higher positivity rate than tested females (p<0.0001). Likewise, symptomatic individuals were more likely to test positive than asymptomatic individuals (p<0.0001). When controlling for symptoms, the positivity rates between males and females were comparable (p=0.97). Pregnant women had a significantly lower positivity rate than non-pregnant women even with controlling for the presence of symptoms (Table 2). The difference in positivity rates among age categories (Table 1) is likely due to the higher proportion of older adults tested due to being symptomatic compared to those of child-bearing age.

Table 2. Positivity rates for specified sub-populations[1] and associated p-values, Illinois, 2016-2017

Population	Positivity Rate (%)	p-value
Males (n=1,093)	4.0	p<0.0001*
Females (n=5,895)	1.4	
Symptomatic individuals (n= 1,023)	11.2	p<0.0001*
Asymptomatic individuals (n= 4,462)	0.2	
Symptomatic males (n=357)	11.2	p=0.97
Symptomatic females (n=665)	11.3	
Pregnant women (n=4,161)	0.3	p<0.0001*
Non-pregnant women (n=659)	10.0	
Symptomatic pregnant women (n=228)	4.4	p<0.0001*
Symptomatic non-pregnant women (n=408)	15.7	

[1]Observations with missing or unknown values were excluded
*Statistically significant

Case characteristics and outcomes

Exposure

The most common risk factor among cases (96.8%) was travel to an area with local Zika transmission (Table 1). The most common travel destinations were Mexico (n=23), Puerto Rico (n=15), Nicaragua (n=12), Dominican Republic (n=9), and Haiti (n=9). Other destinations included countries in South America and the Virgin Islands. No cases were reported as a result of travel to areas in the United States with local transmission. Cases that reported traveling to Florida also reported travel to countries with local Zika transmission. Only one case in Illinois was identified as being due to sexual transmission. The actual number of Zika cases due to sexual transmission is unknown because individuals with travel to areas with local Zika transmission may also have had sexual partners who traveled to these areas.

Symptoms

Among cases, 92.0% reported having at least one symptom of Zika (Table 1). Over half of all Zika cases (63.2%) reported having at least two symptoms. Among symptomatic cases, 90.4% reported rash, 58.3% reported fever, 34.8% reported conjunctivitis, and 1.7% reported arthralgia (Table 3). Other reported symptoms included chills, diarrhea, and neck pain.

Table 3. Symptoms reported by symptomatic Zika cases (n=115)*, Illinois, 2016-2017

Symptom	Number of cases (%)
Rash	104 (90.4%)
Fever	67 (58.3%)
Conjunctivitis	40 (34.8%)
Arthralgia	2 (1.7%)
Other	20 (17.4%)

*Cases could have reported more than one symptom

Birth Outcomes

Among the 125 Zika cases in Illinois, 14 cases were among pregnant women (11.2%). Of these pregnancies, eight resulted in live births, four resulted in spontaneous abortions/termination, and two had unknown birth outcomes due to missing information and one mother moving to a different state. Among the eight documented live births, three were classified as congenital Zika cases because the infant had laboratory evidence of Zika virus within two days of birth.[9] Two of the congenital Zika cases were asymptomatic; one case presented with small lateral ventricles at birth, however there was no further mention of this condition on infant follow-up reports. None of the congenital Zika cases had microcephaly detected at delivery.

Discussion

During January 2016–December 2017, 7,000 individuals tested for Zika were reported to the Illinois Zika surveillance system, and 125 were laboratory confirmed as cases. Travel to areas with active local Zika transmission was the most commonly reported risk factor among cases. Although the majority of tested individuals were asymptomatic, positivity rates were much higher among symptomatic individuals. Nationally, 11.8% of symptomatic individuals tested from January 3–March 5, 2016 had confirmed Zika, which was comparable to the 11.2% positivity rate among symptomatic tested individuals in Illinois.[8] Due to CDC recommendation to test all pregnant women with relevant travel or sexual exposure, regardless of presence of symptoms, testing rates were higher among females and the majority of cases were female. However, males, who were more likely to be tested due to being symptomatic, had a higher positivity rate. The positivity rate for pregnant females in Illinois was only 0.3%, which was comparable to the positivity rate seen nationwide during the first few months of the epidemic: January 3–March 5, 2016 (0.8%).[8]

The epidemic curve of Zika cases in Illinois mirrors that of the United States with the highest number of cases in July 2016 followed by a sharp decline after August 2016.[3] The high positivity rate in January 2016 may be a result of only symptomatic individuals being tested during this

time. Once the testing criteria expanded to include asymptomatic pregnant women in February 2016, there was a dramatic increase in the number of persons tested and a decrease in positivity rate. This trend was also seen in nationally.[8] The decline in Zika incidence in 2017 is likely due to increased immunity among the population in areas with local transmission resulting in decreased infected mosquitoes and fewer travelers becoming infected. Although *Aedes albopictus* mosquitoes, which are capable of transmitting Zika virus, have been found in parts of Illinois, no local transmission has been identified in Illinois to date.

Reporting of negative lab results in I-NEDSS is a unique aspect of Zika surveillance and allowed us to assess positivity rates of Zika among different demographic groups and by risk factor. Once commercial laboratory testing became available and LHDs no longer approved IDPH Zika testing, LHDs began investigating all negative results received by commercial labs for females of child-bearing age to ensure that the correct Zika test was performed. Although receiving negative Zika lab results is beneficial for understanding the overall volume of Zika testing and calculating positivity rates, it also resulted in a large increase in surveillance burden for LHDs with high testing volumes.

This paper is the first comprehensive surveillance summary of Zika virus testing and cases in Illinois and adds to the literature of what is known about Zika surveillance through the use of both positive and negative lab results. A limitation of this analysis is the high percentage of missing data for variables such as presence of symptoms and pregnancy status for the positivity rate calculations. Another limitation is that commercial laboratories may not report all negative Zika results. Since negative lab reporting was not mandated in the Illinois Administrative Code it is possible that the true positivity rates differ from those shown in this report. However, since all testing prior to the development of commercial lab capacity was conducted at public health labs, and clinicians were encouraged to reach out to public health to ensure correct testing was completed, it is thought that the vast majority of negative results were reported.

Although Zika incidence has declined in the U.S., with the high volume of international travel among U.S. residents, there is a high likelihood of the need to begin public health surveillance of additional emerging infectious diseases. Lessons learned from implementation of the Zika surveillance system including the successful use of a Zika module within I-NEDSS; the collection of negative laboratory results to ensure appropriate testing of high risk populations; and the need for better reporting of demographic data can be utilized to improve surveillance efforts for future emerging diseases.

Author Affiliations

1. Illinois Department of Public Health, Office of Health Protection, Division of Infectious Diseases
2. Council of State and Territorial Epidemiologists (CSTE) Applied Epidemiology Fellowship

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Distributions and Trends in Elevated Blood Lead Levels in Adults – Illinois, 2005-2017

Emily Szwiec, MPH[1]
Kimberly Weems, MPH[2]
Linda Forst, MD, MPH[1]
Lee Friedman, PhD[1]
Tiefu Shen, MD, PhD[3]

Abstract

Lead is an agent known to be toxic to humans that can adversely affects multiple organ systems in the human body. Lead exposures can be estimated through blood lead levels. In efforts to monitor the number of individuals in Illinois who are exposed to lead and to reduce the burden associated with lead exposure, the Illinois Adult Blood Lead Registry, in the Division of Epidemiologic Studies, Illinois Department of Public Health (IDPH), tracks cases of elevated blood lead $\geq$10µg/dL as mandated by the Illinois Health and Hazardous Substances Registry Act [410 ILCS 525]. In addition, IDPH in collaboration with the UIC School of Public Health, conducts call backs to gather more information to allow for more careful targeting of preventive efforts. The objective of this report is to analyze the trends in the prevalence of elevated blood lead at reportable levels ($\geq$10µg/dL) between 2005-2017, high levels generally associated with occupational exposures ($\geq$25 µg/dL; also defined as elevated blood lead levels prior to 2013), and very high blood lead levels ($\geq$40 µg /dL).   There were a cumulative of 2,395 unique individuals with one test $\geq$25 aggregated annually between the years 2005-2017, with 530 having levels $\geq$40 µ/dL. The annual prevalence rate went down from 6.44/100,000 employees in 2006 to 2.56 in 2017. The highest rates were observed among workers employed in mining, manufacturing, and gun-firing ranges. When stratified by sub-sector, average annual prevalence rates were highest among battery manufacturing, nonferrous metal shaping and production, and small arms ammunition and ordnance manufacturing; levels were 10-1000 fold higher than the national average. IDPH's collaboration with OSHA has led to site inspections to safeguard Illinois workers.

Introduction

Lead is a naturally occurring inorganic metal found in the soil and is used in many commercial products. Because of the long human history of using lead for many purposes, lead is ubiquitous in the environment and anyone can potentially be exposed. Lead can be absorbed through the skin, by ingestion, or through inhalation. Inhalation of lead fumes is the most efficient mechanism by which the body absorbs lead, and inhalation is the most common route of absorption in occupational settings.[1]

Exposure to lead has been well established to cause toxic and multisystem adverse effects.[2] High blood lead levels at 40 µg/dL or higher in adults are well recognized as being associated with adverse effects on multiple systems[3] such as increased blood pressure, impaired renal function, and cancer.[4] Even low doses of ≤ 10 µg/dL, which previously were thought to be safe, have been shown to have negative health effects on adults, such as increasing all-cause, cardiovascular, and cancer mortality. According to Menki et al, blood lead as low as 2 µg/dL has been associated with

an increase in cardiovascular mortality.[4] Some studies suggest that even at low doses, lead exposure is associated with neurocognitive deficits in adults.[5]

While individuals can be exposed during non-occupational activities, such as remodeling, painting, shooting firearms, or eating food or water which has lead in it, adult lead exposure associated with levels above 10ug/dL primarily occurs at work, which accounts for approximately 95% of reported exposures.[6] The Occupational Health and Safety Administration (OSHA) has set regulations that both the public and private sector must follow. All employees who are exposed to air concentrations at or greater than 30 μg/m^3 for 30 days or more per year must be tested at least every six months to determine blood lead levels. If a worker is found to have a blood lead level of ≥40 μg/dL, they are to be notified in writing and given an exam by a physician. Any construction worker who has a single test which shows a blood lead level ≥60 μg/dL, or >50 μg/dL must be removed from the work place with continued pay and seniority until their level reduces to 40 μg/dL.[2]

Since 1990, the Illinois Adult Blood Lead Registry (ABLR), in the Division of Epidemiologic Studies, Illinois Department of Public Health (IDPH), has conducted surveillance to determine the prevalence of elevated blood lead levels in adults as part of the Illinois Health and Hazardous Substances Registry. This database includes laboratory reports of elevated blood lead levels of adults, defined as at least 16 years of age on the date of the blood draw, for Illinois residents or those who were exposed in Illinois. While not often on the laboratory reports, demographic and occupational information is collected through a follow up survey and was included in this analysis when available. ABLR was also a participant in the Center for Disease Control's (CDC) Adult Blood Lead Epidemiological Surveillance (ABLES) program from 1990 through 2013. Since 1990, the definition of reportable elevated blood lead levels has been ≥25 μg/dL,[7] but was changed in May 2012 to ≥10 μg/dL.[8] The following year, CDC set the reference level for lead in adults at 5ug/dL. This change was in response to CDC's 2010 recommendation. Until this point in time, labs were only mandated to report those who had levels of ≥25 μg/dL.[7]

In an effort to reduce the number of individuals who are exposed to lead and to improve the environment in which employees are exposed, employers, who have at least one case in the database with a blood lead level of ≥ 40 μg/dL, are referred to OSHA by ABLR on a quarterly basis. Employers are notified within 24 hours of receiving the lab report of any case which is ≥60 μg/dL (or >50ug/dL for employees in the construction industry) in order to remove these individuals from exposure promptly.

Data Sources and Methods

Data for this analysis were extracted from the Adult Blood Lead Registry's database and were limited to individuals who were exposed or resided in Illinois with known blood test dates and blood lead levels. All blood samples were collected through venipuncture and tested by a CLIA certified laboratory. Blood lead is a good measure of acute exposures due to lead's short half-life of approximately 35 days in the blood.[1] Based on the definition in 2005, ≥ 25 μg/dL in whole blood is defined as elevated blood lead and very high blood lead is defined as ≥40 μg/dL. Because cases

of 10-25 µg/dL were only available after 2013, only cases above 10ug/dL for years 2015-2017 were utilized.

Laboratories submit test results to ABLR electronically or on paper. Once the test result is electronically or manually entered into a database, patients are matched by date of birth and then by name. Other information, such as sex, race, address, and telephone number, are checked to match, if necessary. For the purposes of this analysis, only the highest test result for each year was used for each patient. Prevalence rates for each year were calculated for both elevated and very high blood lead levels utilizing the number of employed individuals in Illinois for that year as a denominator, as extracted from the Bureau of Labor Statistics.[9] The trend was assessed using simple linear regression and was conducted using SAS version 9.4 (SAS Institute, Inc., Cary, North Carolina).

The proportion of workers with high blood lead levels by industry was calculated for the following three-year intervals: 2005-2007, 2010-2012, and 2015-2017. Average annual prevalence rates were calculated for cases during the years 2015-2017. For work related cases, Quarterly Census of Employment and Wages were used as the denominator for all employees and stratified by industrial sector. This assessment was limited to individuals who had a known work related exposure and had a known industry with a North American Industry Classification System (NAICS) or Standard Industrial Classification (SIC) code. Industries were grouped using the two-digit general industrial classifications in NAICS. In addition, prevalence rates were calculated by country and urban density regions based on the USDA rural-urban codes. The American Community Survey was used for determining the population of residents by county for each year. For this part of the analysis, all cases >10ug/dl were included regardless of whether the exposure occurred at work or somewhere else.

Results

From 2005 to 2017, there were 2,395 individuals who had at least one reported elevated blood lead test >25ug/dL, with 530 of these individuals having at least one test that was a very high blood lead level (≥ 40 µg/dL). The majority of these individuals were male and between the ages of 25 and 64 years old (Table1). Table 2 presents data on adults with blood lead levels >10 ug/dL for years 2015-2017, in accordance with the new reporting requirements. Among this larger group with lower blood lead levels, the distribution by sex, age, race, and exposure was very similar to the group with levels exclusively >25ug/dL.

Table 1: Demographics of individuals in Illinois, aged ≥16 years who had at least one elevated blood lead level >25ug/dL, by year — Adult Blood Lead Registry, Illinois, 2005-2017

Demographic Variables	N (Total 2,395)	%
Sex		
Male	2242	93.61
Female	133	5.55
Unknown	20	0.84
Age at First Test		
16-19	26	1.09
20-24	164	6.85
25-34	483	20.17
35-44	571	23.84
45-54	616	25.72
55-64	388	16.20
65+	137	5.72
Unknown	10	0.42
Race		
White	695	29.02
Non-White	212	8.85
Unknown	1488	62.13
Exposure		
Work Related	1568	65.47
Not work related	106	4.43
Unknown	721	30.10

Table 2: Demographics of individuals in Illinois, aged ≥16 years who had at least one elevated blood lead level >10ug/dL, by year — Adult Blood Lead Registry, Illinois, 2015-2017

Demographic Variables	N (Total 3,768)	%
Sex		
Male	3481	92.38
Female	252	6.69
Unknown	35	0.93
Age at First Test		
16-19	15	0.40
20-24	208	5.52
25-34	684	18.15
35-44	868	23.04
45-54	926	24.58
55-64	867	23.01
65+	200	5.31
Race		
White	1416	37.58
Non-White	534	14.17
Unknown	1818	48.25
Exposure		
Work Related	2652	70.38
Not work related	61	1.62
Unknown	1055	28.00

The prevalence for those with elevated blood lead ranged from 6.44 per 100,000 employed individuals in 2006 to 2.56 per 100,000 employed individuals in 2017 (Table 3). The temporal trend of prevalence was found to be statistically significant and decreased by an average of 0.29 persons per 100,000 employed individuals each year (CI95%: -0.37, -0.20; $p<0.001$; Figure 1). The prevalence for those with very high blood lead ($\geq$40ug/dL) ranged from 1.23 per 100,000 employed individuals in 2012 to 0.29 per 100,000 employed individuals in 2017 (Table 4). The temporal trend for annual prevalence showed a significant decrease by 0.05 per 100,000 per year (CI95%: -0.08, -0.01; $p=0.008$; Figure 2).

Table 3: Prevalence of persons per 100,000 employed individuals, in Illinois, aged ≥16 years who had at least one elevated blood lead level (≥25 µg/dL), by year – Adult Blood Lead Registry, Illinois, 2005-2017

Year	Prevalence Rate (per 100,000 employed)	95% Confidence Interval
2005	6.13	(5.51, 6.76)
2006	6.44	(5.81, 7.06)
2007	6.19	(5.57, 6.80)
2008	5.43	(4.85, 6.01)
2009	4.76	(4.20, 5.31)
2010	4.59	(4.05, 5.13)
2011	4.47	(3.93, 5.01)
2012	5.28	(4.70, 5.86)
2013	4.75	(4.20, 5.30)
2014	4.52	(3.99, 5.06)
2015	3.60	(3.10, 4.10)
2016	2.80	(2.40, 3.30)
2017	2.56	(2.20, 3.00)

Source: Illinois Department of Public Health, Adult Blood Lead Registry, 2005-2014, data as of July 1, 2015; and United States Department of Labor, Bureau of Labor and Statistics, States: Employment status of the civilian non- institutional population by sex, race, Hispanic or Latino ethnicity, marital status, and detailed age, annual averages for 2005, 2006, 2007, 2008, 2009,2010,2011,2012,2013, and 2014. Washington, DC. Available at http://data.bls.gov/search/query/results?cx=013738036195919377644%3A6ih0hfrgl50&q=employed+population.

Figure 1: Prevalence of Individuals with Elevated Blood Lead Levels (≥25 µg/dL)
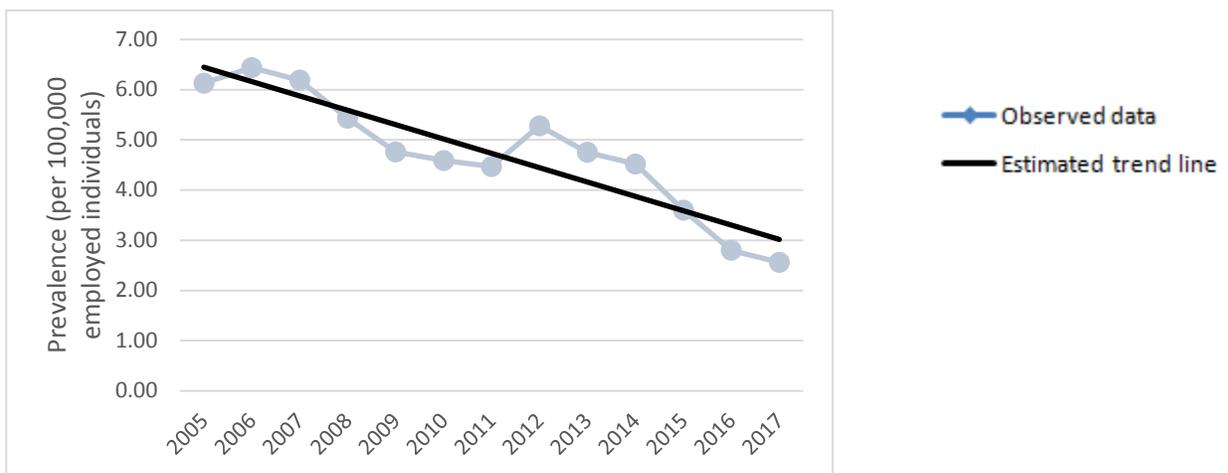
Source: Illinois Department of Public Health, Adult Blood Lead Registry, 2005-2014, data as of July 1, 2015; and United States Department of Labor, Bureau of Labor and Statistics, States: Employment status of the civilian non- institutional population by sex, race, Hispanic or Latino ethnicity, marital status, and detailed age, annual averages for 2005, 2006, 2007, 2008, 2009,2010,2011,2012,2013, and 2014. Washington, DC. Available at http://data.bls.gov/search/query/results?cx=013738036195919377644%3A6ih0hfrgl50&q=employed+population

Table 4: Prevalence of persons per 100,000 employed individuals, in Illinois, aged ≥16 years who had very high blood lead level (≥40 µg/dL), by year — Adult Blood Lead Registry, Illinois, 2005-2017

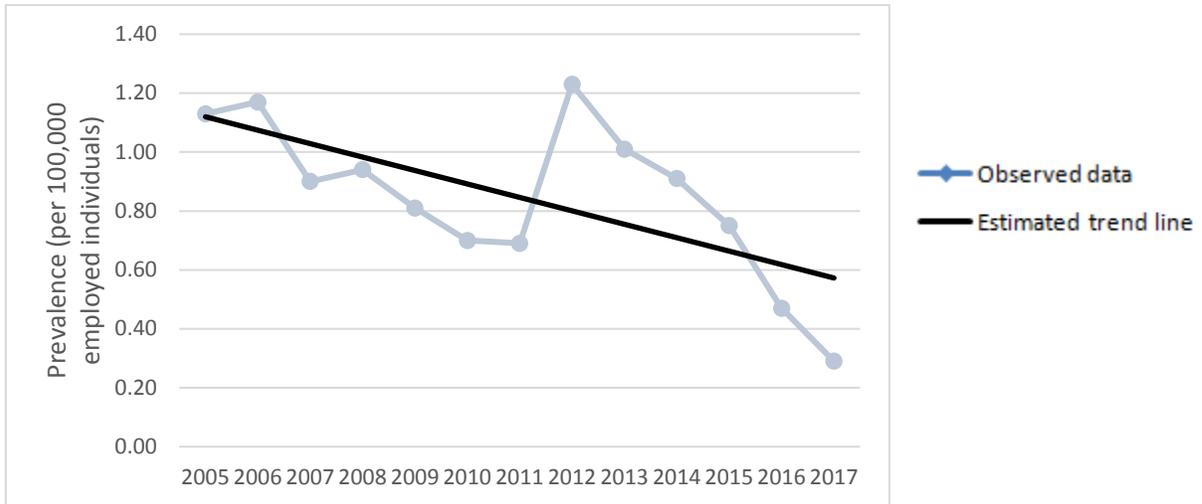| Year	Prevalence Rate (per 100,000 employed)	95% Confidence Interval
2005	1.13	(0.86, 1.40)
2006	1.17	(0.91, 1.44)
2007	0.90	(0.67, 1.13)
2008	0.94	(0.70, 1.19)
2009	0.81	(0.58, 1.04)
2010	0.70	(0.49, 0.92)
2011	0.69	(0.48, 0.90)
2012	1.23	(0.95, 1.51)
2013	1.01	(0.75, 1.26)
2014	0.91	(0.67, 1.15)
2015	0.75	(0.55, 0.97)
2016	0.47	(0.32, 0.69)
2017	0.29	(0.17, 0.46)

Source: Illinois Department of Public Health, Adult Blood Lead Registry, 2005-2014, data as of July 1, 2015; and United States Department of Labor, Bureau of Labor and Statistics, States: Employment status of the civilian non- institutional population by sex, race, Hispanic or Latino ethnicity, marital status, and detailed age, annual averages for 2005, 2006, 2007, 2008, 2009,2010,2011,2012,2013, and 2014. Washington, DC. Available at http://data.bls.gov/search/query/results?cx=013738036195919377644%3A6ih0hfrgl50&q=employed+population

Figure 2: Prevalence of Individuals with Very High Blood Lead Levels (≥40 µg/dL)

Source: Illinois Department of Public Health, Adult Blood Lead Registry, 2005-2014, data as of July 1, 2015; and United States Department of Labor, Bureau of Labor and Statistics, States: Employment status of the civilian non- institutional population by sex, race, Hispanic or Latino ethnicity, marital status, and detailed age, annual averages for 2005, 2006, 2007, 2008, 2009,2010,2011,2012,2013, and 2014. Washington, DC. Available at
http://data.bls.gov/search/query/results?cx=013738036195919377644%3A6ih0hfrgl50&q=employed+population

Information about whether the exposure was work-related was available for approximately 69.9 percent of patients with blood lead levels >25ug/dL. Of the 1,568 individuals who had a known work exposure, industry data was available for 88.8 percent. For the purpose of this analysis, only those who had industry data were included to calculate three-year averages of the work exposure distribution by industry. For those who had elevated blood lead >25ug/dL, the largest change in the proportion of elevated blood lead levels by industry was seen among those employed in amusement and recreation industries (Table 5). These cases are almost entirely employed in gun ranges. The same pattern was observed among with those with very high blood lead levels >40ug/dL (Table 6).

Table 5: Distribution (3-year average) of selected industries among individuals with elevated blood lead levels (≥25 µg/dL) from a known work exposure

Industry	2012 NAICS Codes	2005-2007 (percent)	2012-2014 (percent)	2015-2017 (percent)
Agriculture	11	3.47	11.87	0.00
Mining	21	4.01	10.03	5.37
Utilities	22	0.10	0.00	0.60
Construction	23	5.38	7.43	7.16
Manufacturing	31, 32, 33	73.80	55.76	56.72
Wholesale Trade	42	0.58	0.82	2.09
Retail	44, 45	0.20	6.65	2.09
Transportation and Warehousing	48, 49	2.21	1.46	2.69
Finance and Insurance	52	0.00	0.21	0.00
Professional, Scientific, Technical Services	54	0.38	0.83	0.30
Waste Management and Remediation Services	56	~	~	4.78
Education	61	0.49	0.19	0.30
Amusement and Recreation Industries (Gun Ranges)	71	0.10	0.61	15.52
Other Services	81	0.39	1.02	1.19
Public Administration	92	8.91	3.11	1.19

Table 6: Distribution (3-year average) of selected industries among individuals with very high blood lead levels (≥40 µg/dL) from a known work exposure

Industry	2012 NAICS Codes	2005-2007 (percent)	2012-2014 (percent)	2015-2017 (percent)
Agriculture	11	2.02	9.82	0.00
Mining	21	7.61	12.48	1.89
Utilities	22	0.00	0.00	0.00
Construction	23	10.19	9.33	9.43
Manufacturing	31, 32, 33	60.25	31.17	32.07
Wholesale	42	2.63	0.95	0.00
Retail	44, 45	0.83	24.20	3.77
Transportation and Warehousing	48, 49	5.78	4.21	0.00
Finance and Insurance	52	0.00	0.88	0.00
Professional, Scientific, Technical Services	54	0.00	0.88	1.89
Waste Management and Remediation Services	56	~	~	5.66
Education	61	1.18	0.95	0.00
Amusement and Recreation Industries (Gun Ranges)	71	0.62	0.00	41.51
Other Services	81	0.62	0.00	1.89
Public Administration	92	8.28	5.13	1.89

Table 7 presents the average annual prevalence rates by major industrial sectors and subsectors during the years 2015-2017. The highest rates across all blood lead levels were observed among workers employed in mining, manufacturing, and gun ranges. Among those with very high blood lead levels (>40ug/dL), those employed in gun ranges had the highest prevalence rates out of all industries. When the data was stratified by subsectors, the highest average annual prevalence rates were observed among workers employed in battery manufacturing, nonferrous metal shaping, and other nonferrous metal production. The stratification by subsector also identified a continued pattern among those producing and using firearm related products. The rates in most of these subsectors are 10-1000 fold above the average rates among U.S. adults reported by CDC's ABLES national program.

Table 7: Average Annual Prevalence Rates per 100,000 Workers by Blood Lead Levels and Industry, 2015-2017

Industry	2012 NAICS Codes	BLL >10 ug/dL	BLL >25 ug/dL	BLL >40 ug/dL
Agriculture	11	0.00	0.00	0.00
Mining	21	275.33	71.82	3.99
Utilities	22	24.72	3.53	0.00
Electric power distribution	*22112*	*43.71*	*6.24*	*0.00*
Construction	23	16.35	4.41	0.92
Painting and wall covering contractors	*23832*	*257.95*	*77.87*	*19.47*
Manufacturing	31, 32, 33	117.40	13.14	1.18
Other Basic Inorganic Chemical Manufacturing	*32518*	*1016.73*	*635.46*	*21.18*
Nonferrous metal foundries	*33152*	*1225.73*	*58.84*	*29.42*
Other nonferrous metal production	*331410*	*6211.18*	*3105.59*	*621.12*
Nonferrous metal, except Cu and Al, shaping	*331491*	*10901.96*	*1098.04*	*0.00*
Miscellaneous fabricated metal product manufacturing	*33299*	*809.58*	*238.66*	*14.04*
Small arms ammunition and ordnance manufacturing	*332992 332994*	*2920.67*	*323.40*	*30.32*
Battery manufacturing	*33591*	*46172.54*	*2612.39*	*303.77*
Wholesale	42	5.51	0.77	0.00
Recyclable material merchant wholesalers	*423930*	*253.61*	*30.19*	*0.00*
Retail	44, 45	1.11	0.49	0.14
Sporting goods stores (gun sales)	*451110*	*35.46*	*21.28*	*3.55*
Transportation and Warehousing	48, 49	5.83	1.35	0.00
Finance and Insurance	52	0.00	0.00	0.00
Professional, Scientific, Technical Services	54	0.54	0.11	0.11
Waste Management and Remediation Services	56	4.91	1.25	0.23
Remediation services	*562910*	*1055.41*	*228.67*	*52.77*
Education	61	0.08	0.08	0.00
Amusement and Recreation Industries (Gun Ranges)	71	35.90	25.57	10.82
All Other Amusement and Recreation Industries (Gun Ranges)	*713990*	*129.72*	*91.88*	*39.64*
Other Services	81	1.48	0.85	0.21
Public Administration	92	1.66	0.66	0.17

Geographical Distribution

Table 8 presents the average annual prevalence rates by major urban density areas based on the county of residence for the adults with elevated blood levels >10ug/dL (years 2015-2017). Because lead exposures are not distributed uniformly across the State of Illinois (location of manufacturing plants, gun ranges, etc.), regions with substantially higher average annual rates were expected. The rates were highest in metro areas or counties adjacent to metro areas. The

highest rates per 100,000 residents were observed among those living in Mason, Washington, and Jersey Counties.

Table 8: Average Annual Prevalence Rates per 100,000 Residents by County of Residence Aggregated by Population Density, Blood Lead Levels Above 10ug/dL, 2015-2017
(Specific Counties are Shown Only Where Rates Exceed 20 per 100,000 Residents)

Aggregated Counties by Urban Density Codes (U.S. Department of Agriculture Codes)	Cases BLL >10 ug/dL	Average Annual Prevalence Rate per 100,000 Residents
Counties in metro area with 1 million population or more (n=17)	**2832**	**10.10**
Jersey County	*33*	*49.36*
Calhoun County	*7*	*47.44*
Madison County	*336*	*42.08*
Kane County	*585*	*36.84*
Macoupin County	*49*	*35.41*
Bond County	*18*	*35.39*
Kendall County	*82*	*22.21*
Counties in metro area of 250,000 to 1 million population (n=10)	**200**	**7.17**
Counties in metro area of fewer than 250,000 population (n=9)	**181**	**6.57**
Macon County	*74*	*22.95*
Nonmetro counties with urban population of 20,000 or more, adjacent to a metro area (n=9)	**88**	**6.36**
Livingston County	*27*	*24.46*
Nonmetro counties with urban population of 20,000 or more, not adjacent to a metro area (n=6)	**94**	**9.89**
Williamson County	*67*	*33.09*
Nonmetro counties with urban population of 2,500-19,999, adjacent to a metro area (n=22)	**179**	**12.62**
Mason County	*29*	*70.53*
Washington County	*21*	*49.07*
Fulton County	*34*	*31.71*
Jo Daviess County	*16*	*24.21*
Carroll County	*25*	*56.88*
Nonmetro counties with urban population of 2,500-19,999, not adjacent to a metro area (n=20)	**71**	**7.15**
Nonmetro counties completely rural or less than 2,500 urban population, not adjacent to metro area (n=7)	**8**	**4.90**
Nonmetro counties completely rural or less than 2,500 urban population, adj. to metro area (n=2)	**4**	**12.18**

Site Inspection Interventions

Employers who have workers with elevated blood lead levels $\geq$ 40 µg/dL are referred to OSHA on a quarterly basis through an inter-agency agreement between IDPH and OSHA. Employees are de-identified prior to the referral. OSHA utilizes the information to direct where inspections and interventions are most needed. Table 9 presents the number of referrals from IDPH to OSHA, and the findings and proposed penalties assessed by OSHA. The number of companies referred to OSHA hovered around 20 per year from 2005 to 2014, and was much lower in 2015-6, though the number of OSHA inspections leading to citations remained at one-four throughout the 12-year period. Actual fines are listed in table 9. Data were not available for 2017.

Table 9: Referrals Made by IDPH to the Occupational Safety and Health Administration (OSHA) for Workers with Blood Lead Levels >40ug/dL — Adult Blood Lead Registry, Illinois, 2005-2014

Year	Number of Companies Referred	Inspections Conducted	Proposed Fines
2005	21	0	No data
2006	26	2	No data
2007	15	2	No data
2008	15	2	$14,700
2009	20	3	$18,300
2010	10	1	No citations, company compliant
2011	18	1	No citations, company compliant
2012	20	4	$136,320
2013	16	2	$12,040
2014	17	1 (3 companies were already under inspection by OSHA due to employee complaints)	$10,800
2015	6	2	$17,960
2016	7	4	$12,549

Discussion

From 1994-2011, CDC reported a decline in the prevalence of adult individuals with elevated blood lead levels of $\geq$ 25 µg/dL from 14.0 per 100,000 to 6.4 per 100,000 employed individuals.[2,6] Similar to CDC's report, the prevalence of individuals with elevated blood lead levels in Illinois from 2005 to 2017 has shown a significant decline from 6.13 per 100,000 in 2005 to 2.56 per 100,000 workers in 2017. This trend was found to be equal to approximately 1 person less per 100,000 workers for every four years.

The decline can partly be attributed to changes in industries and/or increased prevention and control of lead exposure. As the economy changed, the industries may have experienced a decline in the number of jobs in which workers were exposed.[6] Manufacturing, which employs the majority of individuals who have elevated blood lead levels, is a prime example of this. As more companies continue to reduce the number of jobs with potential lead exposure, fewer individuals will be exposed in these industries.

Efforts by public health agencies and by regulating bodies may also have contributed to this decline through lead education, industrial hygiene controls, and enforcement activities. In 2008, OSHA changed lead exposure as a point of emphasis and collaborated with CDC's Adult Blood Lead Epidemiology and Surveillance to identify problematic industries. With the change in CDC's definition of elevated blood lead levels from ≥ 25 µg/dL to ≥ 10 µg/dL[10] and an amendment to the Illinois Health and Hazardous Substances Registry Administrative Code, which lowered the level at which tests are mandatorily reported to IDPH to ≥10 µg/dL, more individuals were tested. This increase may have resulted in raised awareness and earlier detection of lead hazards by employers and employees which can lead to earlier remediation activities.[8]

Although unlikely, it is possible that the decline is due to non-compliance of testing by companies and reporting by laboratories. In order to explain this downward trend, the non- compliance would need to be increasing over time. However, it is not possible to determine compliance using the data available in the registry.

With approximately 95 percent of the known exposures being work related, industries likely played a major role in the decline on blood lead levels over this time period. Of individuals with recorded industries information, between 2005 and 2007, manufacturing, public administration, agriculture, mining, and construction account for 95.57 percent of individuals with elevated blood lead level from work, but only 70.4 percent from 2015 to 2017. Only in waste management and remediation services and gun ranges did an increase in the proportion of the overall case mix of blood lead levels >25 ug/dL occur.

However, the average annual prevalence rates by industrial subsector clearly shows that lead exposure is isolated to very specific employers. The highest rates, which exceeded the national average by 100-fold or more, were seen among workers employed in battery manufacturing, nonferrous metal shaping, other nonferrous metal production, and persons employed in the production or use of firearms.

This report has limitations. The prevalence estimated could underestimate the true prevalence in the Illinois adult working population if not all cases tested are reported or those who should be tested are not tested. On the other hand, due to ABLR's incomplete collection on occupation and industry, some of cases may not be work-related, but they were included in the general prevalence estimates, resulting in overestimation of the estimates where industry is not characterized. In addition, lead exposure is cumulative and because lead is readily stored in human bone, blood lead levels may remain elevated for years or decades after the cessation of exposure because of the complex toxicokinetics of lead. Essentially lead in the bones will move

into the blood as the body excretes lead out of the body from the blood. In addition, aging and various bone diseases will lead to movement of bone lead into the blood resulting in increased blood lead levels. Because information on the initiation of exposure in individuals or their comorbidities was not available, cumulative unique cases were included on an annual basis in our prevalence estimates even if their exposures stopped prior to the calendar year. This may result in overestimation of the prevalence estimates.

Further studies are suggested to quantify ABLR's data completeness and quality. ALBR should also conduct follow up surveys to gain more information regarding exposure and demographic information which was also found missing in a substantial number of cases.

Author Affiliations

[1]University of Illinois at Chicago, School of Public Health, Division of Environmental and Occupational Health Sciences, Chicago Illinois, 60612.

[2]University of Illinois at Chicago, School of Public Health, Division of Environmental and Occupational Health Sciences, Chicago, Illinois, 60612 and Illinois Department of Public Health, Office of Policy, Planning and Statistics, Division of Epidemiologic Studies.

[3]Illinois Department of Public Health, Office of Policy, Planning and Statistics, Division of Epidemiologic Studies.

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7. Adult Blood Lead Registry Procedure Manual. IDPH 2009. Version 1; 1-2

8. Illinois Health and Hazardous Substances Registry Act. 77 Ill. Admin. Code 840 Subchapter P § 840.10 & 840.305, (as amended May 18, 2012).

9. United States Department of Labor, Bureau of Labor and Statistics, States: Employment status of the civilian non-institutional population by sex, race, Hispanic or Latino ethnicity, marital status, and detailed age, annual averages for 2005, 2006, 2007, 2008, 2009,2010,2011,2012,2013, and 2014; and Quarterly Census of Employment and Wages for years 2015, 2016, and 2017. Washington, DC. Available at https://www.bls.gov/data/. Accessed May 23, 2018.

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Appendix A

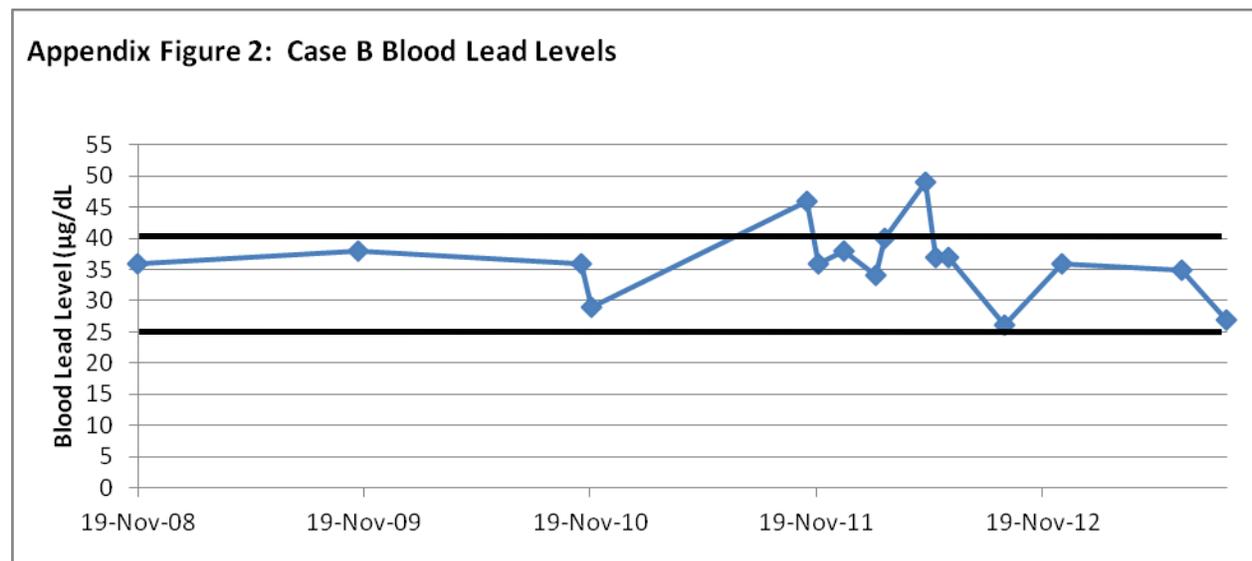**Selected Case Studies**

 Case A:

Case A is a middle aged, male from western Illinois. According to the reports, he has a known occupational exposure and works in the painting and wall covering contractor industry. Over the past 10 years, 21 blood lead tests have been submitted to ABLR, 9 of which have been ≥40 µg/dL. From 2005-2014, his blood lead levels have ranged from 22 µg/dL to 100 µg/dL. His initial blood test in 2006 would have made him a candidate for chelation, which would explain the rapid drop in his blood lead level. It is likely this is also an explanation for the drop from 79 µg/dL in 2010. Based on OSHA regulations, both of these times he should have been removed from the work environment in which he was being exposed to lead and returned only once he had two blood tests which showed a blood lead level below 40 µg/dL.[2] Case A is an example of the cyclical nature of some individuals in the database. While his drop in blood lead levels is likely due to some kind of treatment and work place intervention, it does show how blood lead levels rise again.
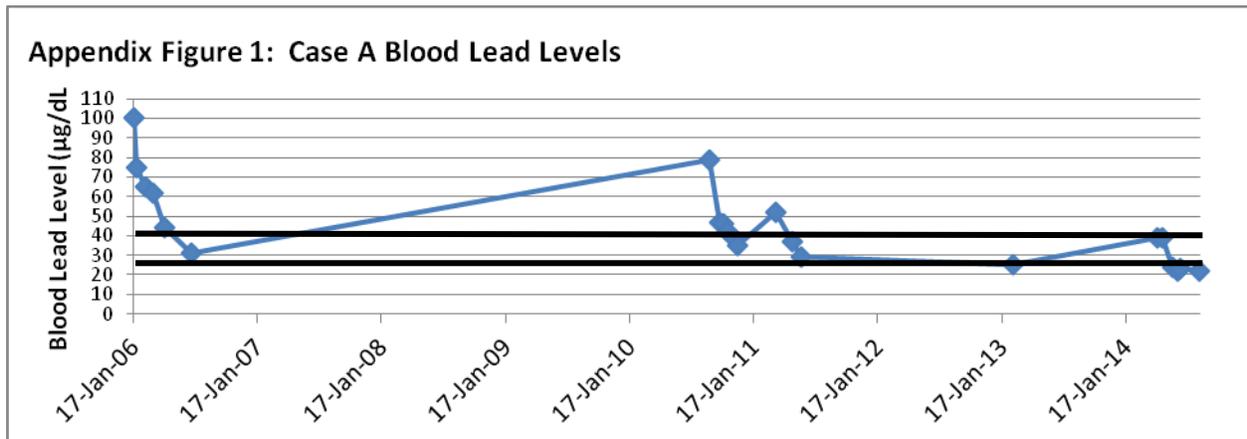
Appendix Figure 1: Case A Blood Lead Levels

Source: Illinois Department of Public Health, Adult Blood Lead Registry, 2005-2014, data as of July 1, 2015

Case B:

Case B is an older male from the Chicagoland area who has no occupational exposure. As confirmed by a doctor, Case B is a firearms enthusiast and was exposed while at a shooting range. Eighteen test results were received for him between 2008 and 2013 with two results ≥40 µg/dL. His blood lead levels have ranged from 27 µg/dL to 49 µg/dL. While not subject to OSHA regulations and guidelines, this individual should show a pattern of testing frequency similar to those who were occupational exposures. From end of 2011 to the end of 2012, this individual was receiving the recommended follow up tests every one to two months. This is likely because of his previous high test results.[2]

Appendix Figure 2: Case B Blood Lead Levels

Source: Illinois Department of Public Health, Adult Blood Lead Registry, 2005-2014, data as of July 1, 2015

Case C:

Case C is a middle aged, male from southern Illinois. It is known that this individual has been exposed in his occupation in the lead or zinc mining industry. From 2007 to 2013, 39 test results have been submitted to ABLR ranging from 18 μg/dL to 42 μg/dL. Three blood tests within a three month range were ≥40 μg/dL. While it is possible that this individual was removed from the exposure during part of this time period, OSHA does not require individuals to be removed unless the blood lead level is ≥60 μg/dL. The decrease in blood lead level is like a response to a decrease in exposure from removal from the exposure, use of personal protective equipment, or other interventions.[2]

Appendix Figure 3: Case C Blood Lead Levels

Source: Illinois Department of Public Health, Adult Blood Lead Registry, 2005-2014, data as of July 1, 2015

Case D:

Case D is a middle aged, white male from Chicagoland area. The individual has a known occupational exposure of working in storage battery manufacturing, but the last three test results list his occupation as nursery and tree production, an occupation in which he is less likely to be exposed. Over the course of the 10 years of the study, 32 blood tests, ranging from 27 µg/dL to 48 µg/dL, have been reported to ABLR with 21 of these tests having a blood lead level of ≥40 µg/dL. These very high test results have occurred in all 10 years present. Case D is an example of the persistently high blood lead levels even after the worker has left the initial job because of the accumulated lead in the body (mainly bone).

Appendix Figure 4: Case D Blood Lead Levels