Factors Associated with the Seasonality of Blood Lead Levels Among Preschool Wisconsin Children

Jeff Havlena, MS; Marty S. Kanarek, PhD, MPH; Margie Coons, RN, MS

INTRODUCTION
Blood lead levels among preschool age children have long been known to follow seasonal trends. As early as 1925, researchers have documented that maximum blood lead levels occur during the summer and late summer months.1 More recently, Laidlaw, Filippelli and other researchers found a distinct seasonal variation of blood lead levels and the incidence of lead poisoning, primarily among children who live in urban areas.2-3 The observed seasonality has been attributed to (1) airborne dust originating from dry summer soils being blown into open windows; (2) children playing outdoors in lead-contaminated soil; (3) lead-contaminated soil tracked into living spaces on shoes and clothing; and (4) seasonally varying levels of vitamin D and calcium in children's blood, and the physiologic effects on the absorption and retention of lead within children's blood. The seasonal component of childhood blood lead is so widely acknowledged that Hunter referred to childhood lead poisoning as the "summer disease."4

Seasonal differences in blood lead levels were well documented during the 1970s and early 1980s by Hunter and others.4-6 These researchers found a distinct seasonal influence on blood lead levels, with the highest levels occurring during the late summer, and lowest levels during late winter and early spring. They postulated that seasonal differences could be caused by various factors such as air pollution and physiological factors that include seasonal variations in the uptake and retention of vitamin D and calcium as well as exposure to soil and dust associated with outdoor play activities and open windows during the warmer months.

Research conducted during the Childhood Lead Exposure Assessment and Reduction Study concluded that some of the seasonal variability in blood lead levels “...is probably due to increased exposure to lead in dust and soil.” The authors used atomic absorption spectrophotometry and mass spectroscopy on samples of indoor dust and outdoor soil at a number of loca-
very conditions when houses are most ‘permeable,’ being open to the exchange between indoor and outdoor environments.

Potential sources of anthropogenic lead in the soil include residual lead from leaded gasoline, lead from industrial processes, and lead particulate from lead-based paint on the exterior of houses and buildings. Laidlaw et al concluded that in many urban settings, residual automotive lead continues to be a significant component of the overall concentration of lead in the soil and outdoor environment.2 Filippelli et al measured the concentration of lead in surface soils adjacent to Indianapolis streets.3 They determined that although the concentration of lead decreased exponentially with distance from the roadways, the low solubility of lead and the presence of grasses (as in front yards and parks) could lead to a concentration of lead in the near-surface soils, where it might be available for transport to children. Physical partitioning of anthropogenic lead into carbonate, iron, and manganese minerals, and the finer, clay-sized soil fractions leads to increased transport and bioavailability. As a result, anthropogenic lead in dust from such soils is considered to be more problematic and pose a greater risk than naturally occurring lead3. This paper explores whether the seasonal behavior and apparent relationship to seasonal environmental influences observed by Laidlaw and others applies to Wisconsin.

Methods

The Wisconsin Childhood Lead Poisoning Prevention Program (WCLPPP) within the state Division of Public Health has tracked childhood lead poisoning in Wisconsin for more than a decade.4 Since the 1994 enactment of State Statutes 254.13 and §254.15, all blood lead levels for tests done on children are reported to the state Division of Public Health, and the results and associated test information entered into a comprehensive database. The WCLPPP maintains all childhood blood lead testing data in the ‘STELLAR’ database, which includes information on the child, the child’s address, his or her attending physician, and test date as well as sample type and result for all tests conducted on Wisconsin children. Among the data collected are test and blood lead level information, along with data about the child’s address and age at the time of the test.

The WCLPPP lead testing data were used to develop analyses of the temporal distribution of mean blood lead levels. Blood lead test results were analyzed for children younger than age 6 (N=676,928 children and 1,168,298 tests; mean monthly number of children tested range
from 6263 for December to 9159 for September), with particular emphasis on infants younger than 10 months of age (n=100,599 infants and 102,616 tests; mean monthly number of infants tested range from 597 for December to 697 for March). Data for infants younger than 10 months was selected because: (1) they were presumed to be too young to walk and consequently not likely to come in direct contact with lead dust on windowsills or outdoor soil, and (2) their blood lead testing histories likely were short and the data not biased by multiple follow-up tests for poisoned children; only 1884 (1.9%) of the tested infants had more than 1 test previously. Infants are assumed to be relatively immobile and not likely to come in direct contact with lead at windows or in the outside soil; however, many likely come in contact with dust on floors and other accessible surfaces. Nearly 80% of the infants included in this study were tested at 8 or 9 months of age (mean=8.5 months; median=8.2 months), possibly associated with their 9-month well child visit. Although the American Academy of Pediatrics guidelines recommend that children be screened at 9-12 months, then again at 24 months, most children receive their 1-year test during their 12-month well child visit.10 It is likely that many of the infants included in the current analysis were tested early because they were perceived to be at risk of exposure to lead in their home.

RESULTS
Figure 1 shows the composite mean monthly blood lead levels for Wisconsin children younger than age 6 for the period 1996 through 2008. The seasonal periodicity is evident, with a classic 6-month annual period between the month with the minimum mean blood lead level (March) and the month with the peak (September). The September peak of 4.96 mcg/dL is 15.9% greater than the March minimum of 4.28 mcg/dL. The mean value for the 6-month peak period from June through November is 9% greater than the mean value for the minimum period December through May. These are composite values, aggregated over the multi-year period from 1996 through 2008. Individual years show greater variability (Figure 2, which is for infants younger than 10 months), as do values for individual children.

Figure 2 shows the time series of monthly mean blood lead levels for Wisconsin infants younger than 10 months for the years 1996 through 2008. This figure shows: (1) a generally downward long-term trend, and (2) an apparent seasonal trend for most years, with peak values typically occurring during late summer, and minimum levels during the late winter.
Figure 3 shows the statewide, 1996-2008 composite monthly mean blood lead levels, along with the number of children tested. This graph shows that there does not appear to be a bias in the mean blood lead levels, in that there is no apparent relationship between the blood lead levels and the number of children tested.

The magnitude and period of the seasonal trends appear to be approximately similar for each geographic region. However, further geographic stratification shows a distinct difference in seasonality between children who live in rural, suburban, and urban settings. The most distinct seasonal trend occurs for census tracts identified by the Census Bureau as being 80%-100% urban (Figure 4). Tracts that fall within this category typically lie within the core central areas of large- and moderate-sized cities. The next most distinct seasonal trend occurs among children who live in census tracts that are considered 0%-20% urban. These tracts are spread throughout the state, comprise the bulk of the land area of Wisconsin, and are typically agricultural areas away from city centers (Figure 5). The intermediate tracts (20%-50% urban and 50%-80% urban) typically lay outside cities, and may be considered to be suburban tracts. The oldest and lowest valued housing occurs most frequently within the 0%-20% and 80%-100% urban tracts, and the highest value and newest housing occurs predominantly in the intermediate (20%-80% urban) tracts.

The monthly maximum 1-hour values for particulate matter smaller than 2.4 microns (PM$_{2.5}$) were examined in order to examine the relationship between windborne dust and the observed trends in blood lead levels. Monthly maximum 1-hour PM$_{2.5}$ values are appropriate for this comparison in that they represent a maximum potential for exposure, rather than an average value. The transport of windblown, lead-containing dust into homes is dependent upon, among other factors, the intensity of the wind and the amount of suspended particulate, rather than the duration of the wind. A short-lived, but intense event could lead to significant transport of particulates into the interior of buildings, especially if the doors and windows were open or in use at the time. Figure 6 shows the mean monthly daily max 1-hour PM$_{2.5}$ values for 4 air quality monitoring stations: Dodge County, Kenosha County, Waukesha County, and Milwaukee County. The seasonal trends are remarkably similar to each other, and to the seasonal trends of mean blood lead levels (Figure 7).
DISCUSSION
There appears to be a strong degree of seasonality of blood lead values across Wisconsin. However, for infants >10 months, this trend appears to be most noticeable within very urban areas and rural settings, and least noticeable in suburban areas. PM$_{2.5}$ data for several stations appears to correlate with the seasonal blood lead trends.

These results appear to be in keeping with the findings of Laidlaw et al who assert that blood lead levels are associated with lead-containing dust, a significant fraction of which arrives from outside the child’s house. Further, the apparent dependence on geographic location could be due to the quality of housing in each of the census areas. Farm houses in the rural tracts and older houses in the city-core census tracts that contain a disproportionate fraction of low valuation, older houses are most likely to be poorly maintained, lack weatherization, and not have air conditioning. All these factors could contribute to the observed seasonal trends, and should be the subject of further study.

In the meantime, parents, health care professionals, public health officials, and others with an interest in reducing the impacts of childhood lead poisoning in Wisconsin should be aware of the seasonal nature of blood lead levels, and consider retesting children who have blood lead results that approach the 10 mcg/dL threshold level during an off-peak period. For example, if a child received his or her 12-month blood lead test in May with a result of 9.0 mcg/dL, the clinician should consider retesting that child during a higher risk period, especially if the child resides in a central city or very rural area.

Furthermore, the geographic variation in seasonality and the trends of blood and PM$_{2.5}$ point to the potential importance of “off-site” sources for lead, and the need to consider airborne sources when evaluating the overall risk to children. If further investigation identifies outdoor sources of lead in soil and wind blown dust, appropriate measures should be taken. These can include methods to increase the ground cover, such as landscaping with grasses or other vegetation (most effectively using plants that are known to remove lead from the soil via phytoremediation), as well as improvements to the child’s house and adjacent structures to reduce the infiltration of dust into the child’s house.

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REFERENCES
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