Bull. Environ. Contam. Toxicol. (2003) 70:409–414

DOI: 10.1007/s00128-003-0001-9

Bulletin of Environmental Contamination and Toxicology

Dentine-Lead Levels and Dental Caries in First Nation Children from the Western James Bay Region of Northern Ontario, Canada

L. J. S. Tsuji,[1] J. D. Karagatzides,[2] R. M. Hanning,[3] B. Katapatuk,[4] J. Young,[1] E. Nieboer[5]

[1] Department of Environment and Resource Studies, 200 University Avenue West, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada
[2] Department of Geography, Queen's University, Kingston, Ontario, K7L 3N6, Canada
[3] Department of Health Studies and Gerontology, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada
[4] Dental Department, Weeneebayko General Hospital, Moose Factory, Ontario P0L 1W0, Canada
[5] Department of Biochemistry, McMaster University, Hamilton, Ontario, L8N 3Z5, Canada

Received: 15 September 2002/Accepted: 20 January 2003

Lead is a ubiquitous toxic metal that can negatively impact the health of organisms exposed to it. For this reason, major progress has been made during the last three decades to decrease the amount and sources of environmental lead, especially in North America (United States Centers for Disease Control [USCDC] 1991). The result of this effort has been a significant reduction in the blood-lead levels of Americans during this period; however, a segment of the American public, the economically deprived, still has a disproportionate number of individuals with blood-lead levels of medical concern (Pirkle et al. 1998). Recently, this segment of American society has also been shown to bear a disproportionate burden of dental caries (i.e., cavities; Vargas et al. 1998). Indeed, a study by Moss et al. (1999), using data from the American Third National Health and Nutrition Examination Survey (NHANES III), was suggestive that environmental lead exposure may be a factor explaining the disproportionately high dental caries burden experienced by this demographic group. They found that blood-lead levels were significantly associated with dental caries burden (primary and secondary dentition), even after adjustment for confounding variables (Moss et al. 1999). The study by these authors verified earlier observations by Brudevold et al. (1977) and Stack (1983) that American children residing in inner-city areas with higher tissue-lead levels, also showed a higher prevalence of dental caries.

In Canada, First Nation people have been shown to live a disadvantaged life with extensive health problems (e.g., Tsuji 1998). For example, the prevalence of dental caries is high in First Nation communities (Harrison and Davis 1993). The switch from a traditional First Nation diet of mainly wild game to one containing both wild game and large amounts of sugar is an important predisposing factor influencing the development of dental caries; other risk factors have yet to be identified (Harrison and Davis 1993). Taking into account that First Nation people are exposed to a recognized environmental source of lead, namely, leaded ammunition used in the harvesting of wild game, it is not surprising that elevated lead levels have been reported in these people, even those living in remote regions of Canada where there are no other substantial sources of environmental lead (e.g., Tsuji et al. 1997; Kosatsky 1998). Recently, we reported that dentine-lead levels were elevated for exfoliated and extracted teeth collected from 149 First Nation children residing in the western James Bay region (Tsuji et al. 2001). In the present paper, we determine if there is any association between dentine-lead levels in exfoliated teeth and dental caries for these same First Nation children.

Correspondence to: L. J. S. Tsuji

MATERIALS AND METHODS

Of the 61 children who donated an exfoliated tooth, during the period 1993 to 1995, as described in the previous study (Tsuji et al. 2001), only 27 were selected for the present study because of exclusion criteria. To be included in the present study, the dental status (condition and history) of all deciduous teeth (FDI nomenclature: tooth no. 55, 54, 53, 52, 51, 61, 62, 63, 64, 65, 75, 74, 73, 72, 71, 81, 82, 83, 84, 85) and the six-year molars (tooth no. 16, 26, 36, 46) for each child had to be clearly discernible from the dental records and a clinical exam. In addition, children showing the clearly recognizable, classic baby bottle caries pattern were excluded, because this environmental factor (i.e., feeding and sleeping with a baby bottle) would mask any relationship between dentine-lead levels and caries. Baby bottle caries has been shown to have a prevalence rate of 53% in Native communities (Harrison and Davis 1993).

All children were examined under a uniform clinical setting, by the same licensed dentist (LJST), during a specified time period when exfoliated teeth were collected; a dental assistant recorded the results. Radiographs were included in the exam, as required. Caries status was evaluated using a modified defs index (defs=d+e+fs), where d refers to the no. of irreversibly decayed teeth, e represents the no. of teeth that were extracted only for carious reasons, and fs refers to the no. of filled surfaces per tooth. Each tooth had five potential surfaces that could have been filled. Carious lesions were defined clinically by cavitation in the enamel surface or the sticking of the explorer in a tooth surface, resisting withdrawal after applying gentle pressure (Harrison and Davis 1993). Radiographically, carious lesions were defined as those involving the dentine; that is, incipient lesions that penetrated the enamel but not the dentine were not considered irreversible carious lesions because of the chance for remineralization. All deciduous teeth and the six-year molars were evaluated for each child to get a single defs index of caries experience. Since, no significant differences have been reported to exist between female and male First Nation children for indices that measured carious activity (Harrison and Davis 1993; cf. non-Native children, Vargas et al. 1998), defs scores for children were not examined separately.

Dentine chips containing primary and secondary dentine were prepared for toxicological analysis as detailed in Tsuji et al. (2001). Tooth type was not considered in the present study because no significant differences in mean dentine-lead levels were found previously within the exfoliated tooth types (Tsuji et al. 2001). Dentine samples were oven-dried to constant weight at 70°C. Samples were digested in 0.5 mL trace-metal grade HNO_3 (JT Baker, Ultrex) for every 0.10 g of dentine. The dentine-acid mixture was digested overnight at room temperature followed by heating at 100°C for 6 hrs. After digestion, samples were diluted with distilled deionized water (DDW) to a final acid concentration of 2.5% v/v. This mixture was filtered through Whatman 42 ashless filter paper. Blanks (trace-metal grade HNO_3) and bonemeal Standard Reference Material 1486 (US National Institute of Standards and Technology [NIST]) were included with each digest run. Lead concentrations were determined with a Perkin-Elmer Model 460 graphite furnace atomic absorption spectrometer, with a detection limit of 0.1 µg/g of dentine. NIST 1643c multi-element reference standard was used in all instrument calibration. Bonemeal reference samples were digested and recovery of lead from them, on average, was within 10% of the expected value (Tsuji et al. 2001).

Confounding factors, such as genetic and socio-economic status, were not considered in the present study because remote First Nation communities in the western James Bay region are typically homogeneous with respect to these factors. A mixedeconomy of subsistence harvesting, wage work and government transfer payments exists in this region; mobility within these income groups is common even within a single year (George 1989).

Data for dentine-lead levels were grouped into two categories following Needleman et al. (1979): low-level (<10 μg/g) and elevated (≥10μg/g). Age of the children for each group was also examined as some researchers (e.g., Curzon and Crocker 1978) have found that age may affect the burden of caries. To equalize the variance of the data, defs data were log transformed. A t-test was used to assess variation in age and defs scores between the lead-determined categories. Linear regression analysis was used to determine the relationship between defs score and dentine-lead level.

RESULTS AND DISCUSSION

A t-test revealed no significant difference between the age of the children in the elevated and low-level lead groups (Table 1). Children in the elevated category had significant higher defs scores than the low-level group (Table 1). Similarly, Brudevold et al. (1977) found that children with high-lead levels in enamel had significantly higher dft (decayed and filled teeth) and dfs (decayed and filled surfaces) scores, than children with low-lead levels. By contrast, Curzon and Crocker (1978) found no association between enamel-lead levels and the prevalence of caries.

A significant relationship (logdefs=0.013Pb+0.856) between defs score and dentine-lead level (P=0.008) was found (Figure 1). Concentration of dentine-lead was used as a chronic measure of lead body burden in comparing variation in defs scores of children with elevated dentine-lead levels and those having low levels. Linear regression analysis revealed that 25% (r=0.50) of the variation in defs score was attributable to variation in dentine-lead level (Figure 1). Among children with low dentine-lead levels, 37% had defs values higher than predicted by the regression equation, while 62% (5 of 8) of children with elevated dentine-lead levels had defs

Table 1. Age, caries experience (defs) and t-tests between First Nation children with elevated dentine-lead (10≥μg/g) and low dentine-lead (<10μg/g) levels.

Character	Elevated $\bar{x}$±sd range (n)	Low-level $\bar{x}$±sd range (n)	t[a]
age, yrs	8±2 6-10 (8)	8±2 6-12 (19)	0.18[ns]
defs	16±5 8-22 (8)	9±4 4-20 (19)	3.47**

[a]Significance of t:**, P<0.01; [ns], P=0.86.

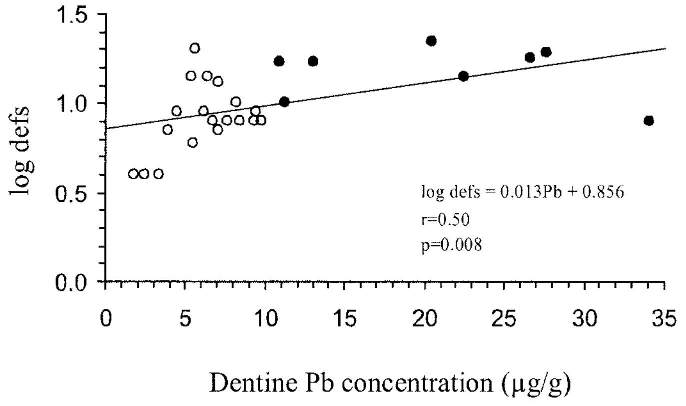

Figure 1. Relationship between log of defs score and dentine-lead level of 27 First Nation children. Children with elevated dentine-lead levels (≥10μg/g) are represented by solid symbols, while children with low-dentine lead levels (<10μg/g) are represented by open symbols.

values greater than predicted. A t-test of residual variation between elevated and low-level children was not significant (t=0.96, P=0.35). Thus, children with elevated dentine-lead levels did not have significantly higher defs scores for their lead level compared to low-level children. However, a tendency towards a disproportionate increase in defs score was noted for children in the elevated dentine-lead group (Figure1).

The effect of outliers (i.e., data points with a standardized residual >±2 sd) was also examined. With the removal of the two outliers, one in each of the two lead groups (i.e., the child with the highest lead value and the child in the low-level group with the highest defs score), the defs scores exhibited a normal distribution. A significant linear relationship (defs=0.547Pb+5.306) between defs score and dentine-lead level (P<0.001) was now evident. Regression analysis revealed an improved fit in that 61% (r=0.78) of the variation in defs score was now attributable to variation in dentine-lead level. Also, among children with low dentine-lead levels, 33% had defs values greater than those predicted by the regression equation, while it was only 43% (3 of 7) for children with elevated dentine-lead levels. A t-test of residual variation between elevated and low-level children was again, not significant (t=0.89, P=0.40). Thus, removal of the outliers affected the slope of the regression line. Our results are in agreement with Gil et al. (1996) who report that in a population of children, teenagers, adults and the elderly living in Coruna, Spain, tooth-lead concentrations (whole teeth) were positively correlated with dental health factors, such as the DMFT (decayed, missing, and filled teeth).

Results of the present study are suggestive that uptake of environmental lead may be one of the factors influencing the disproportionately high rate of dental caries among First Nation children in northern Ontario, Canada. Three mechanisms have been hypothesized to explain how lead may result in an increase in caries. In a study by Watson et al. (1997), it was shown experimentally in rat pups that pre- and perinatal exposure to lead resulted in a 40% increase in prevalence of caries and a 30%

reduction in stimulated parotid function. A decrease in salivary flow could result in an increase in the prevalence of caries because saliva typically buffers the oral cavity and acts to clear sugars from the surfaces of teeth. Lead may also affect teeth directly through the incorporation of lead into the hydroxyapatite crystals of the teeth and/or altered mineralization of the hard tissues of the teeth (Stack 1983; Watson et al. 1997; Moss et al. 1999). Indeed, lead may affect odontoblast function (and other tooth forming cells), as evident by the presence of irregular dentinal tubules and uneven mineralization in lead lines of teeth (Appleton 1991).

It should be stressed that although residence in old, inner-city buildings in the USA, with the associated exposure to leaded paint has been well documented as a major source of environmental lead for disadvantaged children (USCDC 1991; Moss et al. 1999), this line of reasoning is not valid for children of the western James Bay region. Typical routes of lead exposure (i.e., water, soil and air) have been reported to be non-contributory for children of this remote area (Tsuji et al. 2001). First Nation children may be exposed to lead when handling air-gun pellets and/or storing these lead pellets in the mouth prior to discharge (Tsuji et al. 2002), handling ammunition boxes, playing with and/or touching spent lead shotshells, and/or coming into contact with articles of clothing used during harvesting activities in the bush (Tsuji et al. 2001). However, the most likely source of lead exposure is from the ingestion of lead fragments embedded in wild game harvested with lead shotshell (Tsuji et al. 1999; Scheuhammer et al. 1998). Hanning et al. (1996) have even shown significant positive relationships between maternal consumption of wild game and maternal-blood lead, and maternal-blood lead and cord-blood lead. Perhaps, increased exposure to lead while in the prenatal environment and perinatal exposure through cultural activities, such as the harvesting and consumption of wild game with leaded ammunition, are factors that result in an increase risk of dental caries in First Nation communities. Identification of factors that may impact the prevalence of caries in the disadvantaged, including First Nation people, is important because of the morbidity, suffering and financial costs associated with this preventable disease (Harrison and Davis 1993; McDonagh et al. 2000).

Acknowledgments. We thank all the First Nation Band personnel that assisted in this study. Special thanks to the children that kindly donated their exfoliated teeth and the teachers and teaching assistants who collected them.

REFERENCES

Appleton J (1991) The effect of lead acetate on dentine formation in the rat. Arch Oral Biol 36:377-382

Brudevold F, Aasenden R, Srinivasian BN, Bakhos Y (1977) Lead in enamel and saliva, dental caries and the use of enamel biopsies for measuring past exposure to lead. J Dent Res 56:1165-1171

Curzon MEJ, Crocker DC (1978) Relationships of trace elements in human tooth enamel to dental caries. Arch Oral Biol 23:647-653

George P (1989) Native peoples and community economic development in northern Ontario. British J Can Stud 4:58-73

Gil F, Facio A, Villanueva E, Perez ML, Tojo R, Gil A (1996) The association of tooth lead content with dental health factors. Sci Total Environ 192:183-191

Hanning RM, Nieboer E, Moss L, McComb K, MacMillan A (1996) Impact of lead, cadmium and mercury on prenatal and early infant feeding practices of native Indians in the Moose Factory Zone. Abstract 79 Trace Elements in Man and Animals-9, Banff, Alberta, Canada, May 19-24, 1996

Harrison RL, Davis DW (1993) Caries experience of Native children of British Columbia, Canada, 1980-1988. Community Dent Oral Epidemiol 21:102-107
Kosatsky T (1998) Human health risk associated with environmental lead exposure. In: Money S (ed) Hunting with lead shot - wildlife and human health concerns, Canadian Wildlife Service, Hull Canada, p88
McDonagh MS, Whiting PF, Wilson PM, Sutton AJ, Chestnutt I, Cooper J, Misso K, Bradley M, Treasure E, Kleijnen (2000) Systematic review of water fluoridation. British Med J 321:855-859
Moss ME, Lanphear BP, Auinger P (!999) Association of dental caries and blood lead levels. J American Med Assoc 281:2294-2298
Needleman HL, Gunnoe C, Leviton A, Reed R, Peresie H, Maher C, Barrett P (1979) Deficits in psychologic and classroom performance of children with elevated dentine lead levels New England J Med 300:689-695
Pirkle JL, Kaufmann RB, Brody DJ, Hickman T, Gunter EW, Paschal DC (1998) Exposure of the US population to lead, 1991-1994. Environ Health Perspect 106:745-750
Scheuhammer AM, Perrault JA, Routhier E, Braune BM, Campbell GD (1998) Elevated lead concentrations in edible portions of game birds harvested with lead shot. Environ Pollut 102:251-257
Stack MV (1983) Lead. In: Curzon M, Cutress T (eds) Trace elements and dental disease, John Wright, Bristol, UK, 357-385
Tsuji LJS (1998) A decade of change in the Mushkegowuk Territory (1987-1997): moving towards a self-governing health care system. Can J Nat Stud 18:233-254
Tsuji LJS, Nieboer E, Karagatzides JD, Kozlovic DR (1997) Elevated dentine lead levels in adult teeth of First Nation people from an isolated region of northern Ontario, Canada. Bull Environ Contam Toxicol 59:854-860
Tsuji LJS, Nieboer E, Karagatzides JD, Hanning RM, Katapatuk B (1999) Lead shot contamination in edible portions of game birds and its dietary implications. Ecosystem Health 5:183-192
Tsuji LJS, Karagatzides JD, Katapatuk B, Young J, Kozlovic DR, Hanning RM, Nieboer E (2001) Elevated dentine-lead levels in deciduous teeth collected from remote First Nation communities located in the western James Bay region of northern Ontario, Canada. J Environ Monit 3:702-705
Tsuji LJS, Fletcher GG, Nieboer E (2002) Dissolution of lead pellets in saliva: a source of lead exposure in children. Bull Environ Contam Toxicol 68:1-7
United States Centers for Disease Control (1991) Preventing lead poisoning in young children. US Government Printing Office, Atlanta, USA
Vargas CM, Crall JJ, Schneider DA (1998) Sociodemographic distribution of pediatric dental caries: NHANES III, 1988-1994. J American Dent Assoc 129:1229-1238
Watson GE, Davis BA, Raubertas RF, Pearson SK, Bowen WH (1997) Influence of maternal lead ingestion on caries in rat pups. Nat Med 3:1024-1025