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Elevated Blood-lead Levels in First Nation People of Northern Ontario Canada: Policy Implications

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Abstract We evaluated the preliminary impact of the Canadian "non-toxic" shotshell policy, for the hunting of migratory game birds, by examining blood-lead levels of First Nations people living in sub-arctic Canada. If the use of lead shotshell was the major source of lead exposure as has been postulated and the ban on the use of lead shotshell for hunting migratory birds was immediately effective, we would expect that blood-lead levels would be typical of a geographic area remote from industrialization. Our findings present some concern in that approximately 18% of the 196 First Nations people examined had blood-lead levels ≥100 μg/L.

Keywords Blood lead · First Nations · Northern Canada · Lead shotshell

Recently in the United States and several European countries, the use of lead shotshell was banned for waterfowl hunting due to the toxic nature of lead pellets when ingested by waterfowl and raptors (Scheuhammer and Norris 1995). In Canada, the use of lead shotshell was banned nation-wide for only migratory bird harvesting on 1 September 1999 (Environment Canada 2000); thus, in Canada, lead shotshell can still be legally purchased for the harvesting of upland game birds and small mammals. In a study of Cree of the Mushkegowuk Territory (i.e., western James Bay region of northern Ontario; Tsuji and Nieboer 1997), the prevalence of lead pellet exposure via the ingestion of tissue embedded lead pellets and/or fragments was quantified, using radiography. It was shown that approximately 15% of randomly selected radiographic charts, had evidence of lead pellets contained in the digestive tract (Tsuji and Nieboer 1997). Any ingested lead pellet and/or fragment can add to an individuals' lead body burden (Madsen et al. 1988; Gustavsson and Gerhardson 2005). Indeed, edible portions of meat from birds harvested with lead pellets in the Mushkegowuk Territory, showed lead levels >0.5 μg/g wet weight (ww; 33 of 371 samples or 9% of the samples), the level adopted as a human consumption guideline for fish protein in Canada (Tsuji et al. 1999; Scheuhammer et al. 1998). Lead levels in the tissues examined reached 19,900 μg/g ww (Tsuji et al. 1999). Similarly, researchers for the Canadian Wildlife Service have reported that of 827 pooled breast samples from game birds harvested in Canada with lead pellets, 10% of these samples contained lead levels >0.5 μg/g ww (Scheuhammer et al. 1998). In addition, these two studies

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showed (through radiography and atomic absorption spectrometry) that elevated lead levels in game birds were the result of whole and/or lead pellet fragments being embedded in the tissues sampled. It appears that the ingestion of tissue from game birds harvested with lead pellets may be a significant source of lead exposure for First Nation people and other subsistence harvesting groups.

Several studies (e.g., Smith and Rea 1995) have found elevated tissue-lead levels in the First Nation population of the Mushkegowuk Territory, where no other source of lead exposure other than lead-pellet-contaminated meat was found. An association between the consumption of wild meats (mostly waterfowl) and lead in cord and maternal blood was reported for these same First Nation communities (Hanning et al. 2003). Further, Levesque et al. (2003) explored the source of lead exposure in Nunavik (northern Quebec), by determining stable isotope ratios for Inuit and southern Quebec newborns, and found that leaded ammunition was the probable source of contamination for Inuit newborns with atmospheric lead being the source for southern Quebec newborns (Levesque et al. 2003). As a whole, these studies suggest that game birds harvested with lead pellets can be a major source of lead exposure for people who consume traditional foods. In this study, we evaluate the preliminary impact of the “non-toxic” shotshell federal policy on First Nation, blood-lead levels in sub-arctic Canada; while, also establishing baseline data for future studies.

Materials and Methods

Fort Albany and Kashechewan First Nations are located on the Albany River in the western James Bay region of northern Ontario; while, the City of Hamilton is a non-native, industrial community located in southern Ontario, Canada. Only adults (≥18 years old) were recruited for this study from Fort Albany (48 females, 51 males; sample collection fall 1999), Kashechewan (48 females, 50 males; sample collection fall, 1999, and winter, 2000), and Hamilton (27 females, 25 males; sample collection fall, 1999, and winter, 2000).

Subjects were asked to complete a questionnaire in an interview format to collect personal data pertaining to subject identification, demographics, lifestyle, and the level of consumption of traditional foods. A signed consent form was obtained from each participant after reviewing details of the study. This study was approved by the McMaster University Research Ethics Board.

Whole blood samples for lead determination were collected in lavender-top, 6-mL plastic Vacutainer tubes containing the anticoagulant EDTA (Becton–Dickinson). Blood samples were gently mixed, allowed to cool to room temperature, frozen, and stored at –20°C. Blood samples were shipped frozen to the Centre de toxicologie/Institut national de sante publique du Quebec for lead determination.

Lead determination was by electrothermal atomic absorption spectrometry (Perkin Elmer model ZL 4100). Simply, samples were diluted and injected into the instrument. Matrix matched calibration was performed using reference material from the Centre de toxicologie’s inter-laboratory comparison program; while, routine checks for accuracy and precision were also performed using reference material from this program. Periodic evaluations were also performed using external proficiency testing (e.g., US Centers for Disease Control and Prevention). The detection limit (DL) for lead (10 μg/L) was based on three times the average standard deviation of instrumental noise.

Samples with blood-lead levels below the DL limit were imputed as 1/2 DL to allow for statistical analyses. Blood-lead data were grouped by location and sex. Arithmetic and geometric means for blood lead were calculated for both sexes at all locations. Number of individuals having ≥100 μg/L (the blood-lead level of concern for children and women of reproductive age; Health Canada 1995) was determined for both sexes at all locations. The relationship between blood-lead levels and age among individuals (by sex) was assessed by linear regression analysis. Variation in age-adjusted, blood-lead levels between sex and location was assessed by analysis of variance (ANOVA). The relationship between age-adjusted, blood-lead levels and diet was explored. Principal component analysis (PCA) was used to summarize the complete suite of dietary questions as described in Tsuji et al. (2006).

Results and Discussion

Descriptive statistics are presented in Table 1. Participants with blood-lead levels ≥100 μg/L are as follows: Fort Albany, females 4/49, males 13/48; Kashechewan, females 3/48, males 16/51; Hamilton, males 0/25, females 1/27. Our findings present some concern in that a relatively large proportion of people living in the First Nations examined had blood-lead levels >100 μg/L. Hypertension may be an issue as both systolic and diastolic blood pressures are increased by blood-lead concentrations in the 100–200 μg/L in both males and females (ATSDR 2005).

Significant, positive relationships were found between blood-lead levels and age for the sexes (females: $r^2 = 0.16$, $p < 0.0001$; males: $r^2 = 0.04$, $p < 0.02$) although the amount of variation explained was low. ANOVA revealed significant main effects (location, $p < 0.0001$; sex,

Table 1 Comparison of blood-lead concentration to other Aboriginal studies in Canada

Author	Location	Group	Age (years)	n	Geometric mean (μg/L)	Mean (μg/L)	±SD	Min. (μg/L)	Max. (μg/L)
Present study	Fort Albany, Ontario	Females (Cree)	≥18	49	35	44	32	5	137
		Males (Cree)	≥18	48	60	72	43	17	178
	Kashechewan, Ontario	Females (Cree)	≥18	48	33	44	39	9	174
		Males (Cree)	≥18	51	65	78	45	9	166
	Hamilton, Ontario	Females (non-native)	≥18	27	24	29	21	12	110
		Males (non-native)	≥18	25	21	25	16	9	68
Butler Walker et al. (2006)	Arctic Canada	Maternal	15–45						
		Dene/Metis		92	31			5	112
		Inuit		146	32			2	178
Bussieres et al. (2004)	Ouje-Bougoumou, Quebec	Males and females (Cree)	≥15	169	21				
	Nemaska, Quebec	Males and females (Cree)		71	21				
Hanning et al. (2003)	Mushkegowuk territory, Ontario	Maternal (Cree)		83		23	12	6	12
Dewailly et al. (2001)	Nunavik, Quebec	Male (Inuit)	≥18	209	100			17	348
		Female (Inuit)	≥18	283	79			8	475

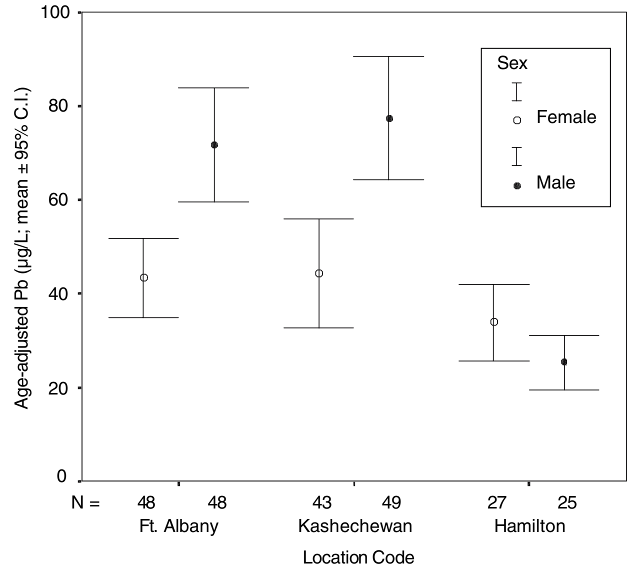

Fig. 1 Plot of age-adjusted blood means and 95% confidence intervals for the remote First Nations communities of Fort Albany and Kashechewan, and the industrial city of Hamilton, Ontario, Canada

$p = 0.0003$) but also a significant interaction of location × sex ($p = 0.002$). Because the significance of the main effects were orders of magnitude greater than that of the interaction, we felt it worthwhile to explore the data further by plotting the age-adjusted blood means (Fig. 1). It is clear that the residents of Fort Albany and Kashechewan have higher body burdens of lead than residents of Hamilton (and comparable to other First Nation groups; Table 1), even though the Hamilton area is highly industrialized. Occupational exposure is not a serious issue in these First Nation communities as there are no formal industries established, and other sources of lead exposure have been shown not to be a factor (Smith and Rhea 1995). Consequently, the gender difference observed for First Nations (Fig. 1) is likely related to the use of leaded ammunition (typically by males) and the consumption of wild meats obtained through hunting.

Significant ($p \leq 0.027$, $r^2 = 0.12$) relationships between age-adjusted, blood-lead levels and PCA-1 ($m = 9.97$), and PCA-3 ($m = -6.21$) were found; non-significant relationships were noted for PCA-2 and 4 ($p \geq 0.09$). PCA-1 explained 39.6% of the variance in the original matrix; people with relatively high values on PCA-1 consumed relatively more wild game, especially waterfowl (loading = 0.846; Tsuji et al. 2006). While individuals with relatively high values on PCA-3 consume relatively more market-bought fish; PCA-3 accounted for 13.7% of the total variance (Tsuji et al. 2006). The finding of only a weak positive relationship between age-adjusted, blood-lead levels and the diet variable (i.e., PCA) representing wild game was not unexpected in that not every piece of meat from wild game will be contaminated with lead pellets and/or fragments. Moreover, in matched (left and right) breast samples taken from the same bird harvested with lead shotshell, it has been shown that lead concentrations in the tissue can vary by several orders of magnitude (Schuehammer et al. 1998; Johansen et al. 2001).

If the use of lead shotshell was the major source of lead exposure in these First Nation communities as has been postulated (e.g., Smith and Rea 1995) and the ban on the use of lead shotshell for the harvesting of migratory game was immediately effective, we would expect that blood-lead levels would be typical of a geographic area remote from industrialization, taking into account that blood lead is reflective of acute exposure (although there is input from endogenous sources of lead, i.e., bone; Gulson et al. 1995). One explanation is that since lead shotshell was just banned in 1999, people still had a supply of lead shotshell and were using up these supplies (Tsuji 1998). Another explanation is that in remote regions of North America, the lead shotshell ban is virtually unenforceable (Tsuji 1998; Balogh 1999). As steel shotshell (a "non-toxic" alternative to lead) is much more expensive than lead to purchase (more than two times the price of lead shotshell; Tsuji 1998) and since, lead shotshell is still legally available Canada-wide (for hunting upland game and small mammals), there is little economic incentive for disadvantaged people to switch (Tsuji 1998; Balogh 1999).

At present, there are no federal laws restricting the chemical composition of the ammunition that can be used to harvest upland game birds because these birds are typically non-migratory (Scheuhammer et al. 2003) and fall under the jurisdiction of the provincial governments (see for e.g., Ontario Provincial Offences 1999). Only migratory game birds are regulated by the federal "non-toxic" shot policy under the Migratory Birds Act (Environment Canada 2000). Thus, to remove a readily available source of lead shotshell, the use of lead shotshell for the harvesting of all wild game should be banned as any wild game harvested with lead pellets may become contaminated with lead pellets and fragments (Tsuji et al. 1999) to a point where the game meat is of toxicological concern with respect to human consumption. Programs that have been proven to be successful in Alaska to convince subsistence hunters to switch from using lead shotshell (as hunting waterfowl with lead shotshell was banned US-wide in 1991) have included a box-for-box swap of steel shotshell for lead, and a way to get steel shotshell to the people in Alaska at a price comparable to lead (the US Fish and Wildlife Service worked with ammunition manufacturers on this aspect of the program; Balogh 1999). Similar programs have been proposed for the Mushkegowuk Territory but have yet to be implemented. Thus, until lead shotshell is banned for all wild game hunting, we believe that elevated blood-lead levels will continue to be observed in populations who partake in traditional hunting pursuits and consume game meats harvested with lead shotshell.

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References

ATSDR (2005) Toxicological profile for lead (draft). US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, USA. http://www.atsdr.cdc.gov/toxprofiles/tp2.html. Accessed 27 February 2007

Balogh G (1999) Lead and the spectacled eider. Endangered Species Bull 24:6

Bussieres D, Ayotte P, Levallois P, Dewailly E, Nieboer E (2004) Exposure of a Cree population living near mine tailings in northern Quebec (Canada) to metals and metalloids. Arch Environ Health 59:732–741

Butler Walker J, Houseman J, Seddon L, McMullen E, Tofflemire K (2006) Maternal and umbilical cord blood levels of mercury, lead, cadmium, and essential trace elements in Arctic Canada. Environ Res 100:295–318

Dewailly E, Ayotte P, Bruneau S, Lebel G, Patrick L, Weber J-P (2001) Exposure of the Inuit population of Nunavik (arctic Quebec) to lead and mercury. Arch Environ Health 56:350–357

Environment Canada (2000) Migratory birds hunting regulations, 2000. Environment Canada, Ottawa

Gulson BL, Mahaffey KR, Mizon KJ, Korsch MJ, Cameron MA, Vimpani G (1995) Contribution of tissue lead to blood lead in adult female subjects based on stable lead isotope methods. J Lab Clin Med 125:703–712

Gustavsson P, Gerhardson L (2005) Intoxication from an accidentally ingested lead shot retained in the gastro-intestinal tract. Environ Health Perspect 113: 491–493

Hanning RM, Sandhu R, MacMillan A, Moss L, Tsuji LJS, Nieboer E (2003) Impact on blood Pb levels of maternal and early infant feeding practices of First Nation Cree in the Mushkegowuk Territory of northern Ontario, Canada. J Environ Monit 5:241–245

Health Canada (1995) Health and environment: a handbook for health professionals. Health Canada, Ottawa

Johansen P, Asmund G, Riget F (2001) Lead contamination of seabirds harvested with lead shot – implications to human diet in Greenland. Environ Pollut 112:501–504

Levesque B, Duchesne JF, Gariepy C, Rhainds M, Dumas P (2003) Monitoring of umbilical cord blood lead levels and sources assessment among the Inuit. Occup Environ Med 60:693–695

Madsen HHT, Kkjom T, Jorgensen PJ, Grandjean P (1988) Blood levels in patients with lead shot retained in the appendix. Acta Radiol 29:745–746

Ontario Provincial Offences (1999) Justice of the peace, 1999 edn. Ontario Government, Toronto

Scheuhammer AM, Norris SL (1995) A review of the environmental impacts of lead shotshell ammunition and lead fishing sinker products in Canada. Canadian Wildlife Service Occasional Paper Number 88, Ottawa

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

Scheuhammer AM, Bond DE, Burgess NM, Rodrigue J (2003) Lead and stable lead isotope ratios in soil, earthworms, and bones of American woodcock (Scolopax minor) from eastern Canada. Environ Toxicol Chem 22:2585-2591

Smith LF, Rea E (1995) Low blood lead levels in northern Ontario – what now? Can J Pub Health 86:373–376

Tsuji LJS (1998) Mandatory use of non-toxic shotshell for harvesting of migratory game birds in Canada: cultural and economic concerns. Can J Native Stud 18:19–36

Tsuji LJS, Nieboer E (1997) Lead pellet ingestion in First Nation Cree of the western James Bay region of northern Ontario, Canada: implications for a nontoxic shot alternative. Ecosyst Health 3:54–61

Tsuji LJS, Nieboer E, Karagatzides JD, Hanning RM, Katapatuk B (1999) Lead shot contamination in edible portions of game birds and its dietary implications. Ecosyst Health 5:183–92

Tsuji LJS, Wainamn BC, Martin ID, Weber J-P, Sutherland C, Nieboer E (2006) Abandoned mid-Canada radar line sites in the western James Bay region of northern Ontario Canada: a source of organochlorines for First Nations people? Sci Tot Environ 370:452–466