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Assessing determinants of maternal blood concentrations for persistent organic pollutants and metals in the eastern and western Canadian Arctic

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HIGHLIGHTS

- In 2005–07, younger age was related to lower levels of chemicals in northern Canada.
- Eastern Inuit who consumed marine mammals showed elevated levels for POPs and Hg.
- Non-diet effects may contribute to chemical concentrations in Arctic aboriginal groups.
- Positive associations between smoking and contaminant levels require more study.

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ABSTRACT

Aboriginal peoples in the Canadian Arctic are exposed to persistent organic pollutants (POPs) and metals mainly through their consumption of a traditional diet of wildlife items. Recent studies indicate that many human chemical levels have decreased in the north, likely due to a combination of reduced global chemical emissions, dietary shifts, and risk mitigation efforts by local health authorities. Body burdens for chemicals in mothers can be further offset by breastfeeding, parity, and other maternal characteristics.

We have assessed the impact of several dietary and maternal covariates following a decade of awareness of the contaminant issue in northern Canada, by performing multiple stepwise linear regression analyses from blood concentrations and demographic variables for 176 mothers recruited from Nunavut and the Northwest Territories during the period 2005–2007. A significant aboriginal group effect was observed for the modeled chemicals, except for lead and cadmium, after adjusting for covariates. Further, blood concentrations for POPs and metals were significantly associated with at least one covariate of older age, fewer months spent breastfeeding, more frequent eating of traditional foods, or smoking during pregnancy. Cadmium had the highest explained variance (72.5%) from just two significant covariates (current smoking status and parity).

Although Inuit participants from the Northwest Territories consumed more traditional foods in general, Inuit participants from coastal communities in Nunavut continued to demonstrate higher adjusted blood concentrations for POPs and metals examined here. While this is due in part to a higher prevalence of marine mammals in the eastern Arctic diet, it is possible that other aboriginal group effects unrelated to diet may also contribute to elevated chemical body burdens in Canadian Arctic populations.

1. Introduction

The presence of persistent organic pollutants (POPs) and metals in the blood and other tissues of people from the Canadian Arctic and other circumpolar nations is well documented. Although there are natural and point sources of these chemicals (Kirk et al., 2012), global pollution and long-range atmospheric transportation are the main sources in the Arctic (Macdonald et al., 2000). Because of their physical–

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chemical properties, these chemicals can biomagnify through the marine food web system and can reach high concentrations in predatory species such as marine mammals (Borgå et al., 2004; Braune et al., 2005). Aboriginal populations in northern Canada are thus at higher risk of exposure to POPs and metals because of their traditional diet (Van Oostdam et al., 2005; Donaldson et al., 2010). This is especially true for Inuit populations who rely more extensively on marine mammals, such as seal and whale (Kuhnlein et al., 2000; Potyrala et al., 2008). Consequently, coastal Inuit populations from Nunavut and Nunavik (in northern Québec) have shown higher concentrations of POPs and mercury in their blood than their non-coastal counterparts from the Northwest Territories who are more likely to consume inland items such as fish and caribou (Muckle et al., 2001; Butler Walker et al., 2003, 2006; Dewailly et al., 2007; Donaldson et al., 2010; Curren et al., 2014).

Increased exposure to metals and POPs has been linked to a wide array of potentially adverse health outcomes, particularly for the developing fetus along with subtle health effects that persist into childhood (Dewailly et al., 2000; Dewailly and Weihe, 2003; Dallaire et al., 2006; Gilman et al., 2009; Boucher et al., 2010, 2012a,b; Ethier et al., 2012). Accordingly, human biomonitoring studies conducted in the Canadian Arctic across 1992–2007 have frequently examined expectant women to elucidate risk for the child (Donaldson et al., 2010). During a similar period, northern studies have extended tissue collection to both men and women, such as through the International Polar Year Inuit Health Survey in 2007–2008 (Saudny et al., 2012; Laird et al., 2013), to better understand exposures within the entire adult populations and also across generations of aboriginal peoples whose modern dietary preferences may be shifting away from certain traditional foods. Dietary choice in the Arctic, and thus extent of exposure to certain foodborne chemicals, is a complex contemporary issue because the substantial cultural and nutritional benefits of traditional foods (Donaldson et al., 2010; Egeland et al., 2011) may be offset by concern for contaminants in some populations. Moreover, dietary shifts to certain market foods may result in higher exposures to other environmental contaminants (Binnington et al., 2014).

Maternal studies conducted in the mid to late 1990s under the auspices of the Northern Contaminants Program (NCP) established a baseline of exposure for people from the Canadian Arctic. Blood collected in the subsequent decade during follow-up studies indicated that concentrations of many organochlorine pesticides and polychlorinated biphenyls (PCBs) declined in aboriginal women from Nunavut, the Northwest Territories, and Nunavik, oftentimes by 50–75% across studies (Donaldson et al., 2010). These observations suggest positive outcomes for POP regulations (such as the Stockholm Convention on Persistent Organic Pollutants) that have been enacted to protect environmental and human health. However, the trend for mercury is less clear. Both increasing and decreasing trends have been observed in Arctic biota (Braune et al., 2005; Rigét et al., 2011). Human blood levels in the Canadian Arctic appear to show a general decline (Donaldson et al., 2010), which may reflect the compliance to health messaging concerning lower mercury intake or simply a result of dietary change of consuming less country foods. Body burden of cadmium has consistently been very high in NCP studies because of the high rate of smoking among aboriginal adults (Donaldson et al., 2010).

The purpose of this study is to investigate the relationship between body burdens of POPs and metals with lifestyle and dietary factors in pregnant women from the Inuvik Region of the Northwest Territories and the Baffin Region of Nunavut who participated in follow-up studies conducted in 2005–2007. To our knowledge, these studies provide the most current information of maternal levels of chemicals for aboriginal populations in these regions. This analysis examines aboriginal group and geographic differences (after adjusting for covariates) to obtain insight on the impact of diet and other behavioral choices for mothers (and, by extension, their unborn children) during this period. Further declines in human levels of POPs and metals in northern Canada are anticipated. The outcome of this analysis will inform study design for the next generation of human biomonitoring activities in the Canadian Arctic, along with public intervention and educational initiatives by local health authorities concerning dietary exposures to chemicals.

2. Methods

2.1. Study description

The Northern Contaminants Program (NCP) of Aboriginal Affairs and Northern Development Canada supported maternal biomonitoring studies in the Inuvik Region of the Northwest Territories in 2005–2006 (Armstrong et al., 2007) and the Baffin Region of Nunavut (Potyrala et al., 2008) in 2005–2007. All mothers who volunteered were sampled due to small population sizes in order to create these convenience samples of northern women. Signed informed consent was obtained from each participant. The study protocols were reviewed and approved by the research ethics boards of Health Canada and for each of the participating centers and health authorities, as appropriate. In addition to providing blood samples late in the third trimester or shortly (e.g., within one day) after giving birth, study participants completed a questionnaire given in person by an interviewer and provided information on variables such as age, smoking behavior, number of children (parity), breastfeeding history, aboriginal group, and estimated consumption frequency for fish and traditional foods. Food frequencies of five main traditional food groups (fish, land animals, marine mammals, birds, and plant foods) were compiled from participant questionnaire responses for a large number of fish and traditional foods. Except for fish, consumption frequency for non-traditional foods was not examined, because levels of POPs and metals in traditional foods were expected to be appreciably higher than for market foods. The total frequency of eating each traditional food group was derived by adding together the number of times each individual food in that group was consumed in the previous year (which included the 9 months of pregnancy and the 3 months prior to pregnancy, recorded as a weekly or monthly frequency). Total frequency of eating traditional foods equals the sum of the frequencies of eating all food groups.

POPs and metals were analyzed in plasma and whole blood, respectively. Chemicals common to both studies are reported here. All of these chemicals had a minimum of 70% of the observations above the limit of detection (LOD) for each aboriginal study group: p,p′-dichlorodiphenyldichloroethylene (p,p′-DDE), oxychlordane, trans-nonachlor, four polychlorinated biphenyl congeners (PCB-118, -138, -153, and -180), and four metals (cadmium, lead, selenium, and total mercury). Blood was taken from the antecubital vein into purple-top, EDTA-containing Vacutainer® tubes. Plasma was obtained by centrifugation and was then decanted into pre-cleaned vials and stored frozen before being shipped frozen for subsequent analysis at the Institut national de santé publique du Québec (INSPQ) in Québec City, Canada. All of the POPs were identified and quantified via gas chromatography/mass spectroscopy (GC–MS) with electronic impact ionization using an in-house accredited method, while concentrations of metals were measured in whole blood by either inductively coupled plasma mass spectrometry (ICP-MS) or cold vapor atomic absorption (total mercury) (Butler Walker et al., 2003, 2006). Prior to GC–MS, plasma samples were extracted on a solid phase extraction (SPE) column, then purified on a Florisil column and concentrated to a final volume. Reported previously (Foster et al., 2012), analyte concentrations were evaluated by considering the % recovery of labeled internal standards. The INSPQ participates in two interlaboratory comparison programs to verify the accuracy of results, in addition to routine analysis of reference serum supplied by the US National Institute of Science and Technology. Quality control data within each analytical run were compared to the control limits to evaluate the validity of analyses using Westgard rules (Westgard, 2002).