Dietary Advice on Inuit Traditional Food Use Needs to Balance Benefits and Risks of Mercury, Selenium, and n3 Fatty Acids1–3

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Abstract

Elevated concentrations of mercury (Hg) are commonly found in the traditional foods, including fish and marine mammals, of Inuit living in Canada’s Arctic. As a result, Inuit often have higher dietary Hg intake and elevated Hg blood concentrations. However, these same traditional foods are excellent sources of essential nutrients. The goals of this study were 1) to identify the traditional food sources of Hg exposure for Inuit, 2) to estimate the percentage of Inuit who meet specific nutrient Dietary Reference Intakes and/or exceed the Toxicological Reference Values (TRVs), and 3) to evaluate options that maximize nutrient intake while minimizing contaminant exposure. A participatory cross-sectional survey was designed in consultation with Inuit in 3 Canadian Arctic jurisdictions (Nunatsiavut, Nunavut, and the Inuvialuit Settlement Region). Estimated intakes for EPA (20:5n3) and DHA (22:6n3) met suggested dietary targets, and estimated selenium (Se) intake fell within the Acceptable Range of Oral Intake. Estimated intakes of Hg (\( r_s = 0.41, P < 0.001 \)), Se (\( r_s = 0.44, P < 0.001 \)), EPA (\( r_s = 0.32, P < 0.001 \)), and DHA (\( r_s = 0.28, P < 0.001 \)) were correlated with their respective blood concentrations. Mean estimated Hg intake (7.9 µg · kg\(^{-1} \) · wk\(^{-1} \)) exceeded the TRV of 5.0 µg · kg\(^{-1} \) · wk\(^{-1} \), with 35% of the population above this guideline. Because the estimated intakes of each of the nutrients were strongly correlated (Se: \( r_s = 0.92, P < 0.001; \) EPA: \( r_s = 0.82, P < 0.001; \) DHA: \( r_s = 0.81, P < 0.001 \)) with estimated Hg intake, efforts to decrease Hg exposure must emphasize the overall healthfulness of traditional foods and be designed to prevent concomitant harm to the nutrient intakes of Inuit. J. Nutr. 143: 923–930, 2013.

Introduction

The Inuit are a group of indigenous peoples inhabiting the Arctic regions of Greenland, northern Canada, Alaska, and Chukotka in Russia with a total population of ~167,000. The Inuit population in Canada comprises 50,000 individuals (1). Traditional foods provide Inuit with a host of benefits, ranging from cultural to economic and nutritional benefits. The social interactions and community sharing central to traditional food reliance is a cornerstone of Inuit culture (1). For people with access to hunting equipment, wild game, fowl, fish, and marine mammals are often the most affordable of foods (2). In addition to these very important social, cultural, and economic benefits, nutrient composition analysis has shown that traditional foods provide excellent sources of protein, long-chain (LC) n3 fatty acids, selenium (Se), iron (Fe), zinc (Zn), and vitamins A, D, and E (3–7). As such, on days when Inuit adults consumed traditional foods, intakes of numerous vitamins and minerals were significantly higher (\( P < 0.01 \)) than on days without traditional food consumption (8). Caribou meat, one of the most frequently consumed foods across the Arctic, has similar crude fat content to lean beef but has higher levels of PUFAs (9). In addition, fish and marine mammal consumption provides Inuit with higher intakes of LC fatty acids such as EPA (20:5n3) and DHA (22:6n3) than does the typical North American diet (6,8,10). In addition to their nutritional density, the hunting and preparation of traditional foods promotes physical activity and their consumption may be associated with lower risk of chronic diseases such as obesity and diabetes (4). These numerous benefits have prompted federal, provincial,
and territorial nutritional education programs to emphasize the importance of traditional foods for First Nations, Métis, and Inuit communities in Canada (11).

Mercury (Hg) is a global pollutant that has been shown to affect the neurodevelopment of children (12). Elevated concentrations of Hg have been reported in marine mammals and human populations in the Arctic because of bioaccumulation and biomagnification (1). For example, Inuit in Arctic Canada had higher blood Hg concentrations than those of the general population in Canada; geometric mean Hg concentrations in Inuit adults from Nunavik was 53.2 nmol/L in 2004 (13), whereas geometric mean concentrations in adult participants of cycle 1 of the Canadian Health Measures Survey (2007–2009) was 4.1 nmol/L (14). Elevated blood concentrations were also found in Inuit women of childbearing age, who represent a subpopulation sensitive to the effects of Hg (14–16). These elevated blood Hg concentrations observed in Inuit communities in Canada are due to the high Hg concentrations in some of the key traditional foods such as ringed seal (Pusa hispida) and beluga whale (Delphinapterus leucas) (17). These exposures have been associated with subclinical biochemical effects in Inuit adults (13), increased systolic blood pressure in Inuit adults (18), and sensory function in Inuit children (19). Consequently, food consumption advisories warning the public of contaminant risks from marine mammal consumption have, in some instances, been found necessary for the protection of public health (20,21). However, given the chronic food insecurity issues that trouble Inuit communities in Canada’s Arctic (22,23), it is imperative for health professionals to also consider the potentially negative nutritional outcomes that could be associated with such advisories.

The primary research objective of the current article was to identify which traditional foods contributed most to the dietary intakes of Hg and Se, EPA, and DHA for participants in the Canadian International Polar Year Inuit Health Survey. Se, EPA, and DHA were selected for evaluation in this study because traditional foods are especially rich in each of these nutrients (24). In addition, we evaluated the percentage of survey participants who exceeded the Toxicological Reference Value (TRV) for Hg and who met Health Canada’s DRI for each of the studied nutrients. Finally, an attempt was made to develop dietary intervention options that promote nutrient adequacy while minimizing Hg intake.

Participants and Methods

International Polar Year Inuit Health Survey. The International Polar Year Inuit Health Survey (IHS) was conducted in 3 Inuit jurisdictions in northern Canada [Inuvialuit Settlement Region (ISR), Nunavut, and Nunatsiavut] in 2007 and 2008 (Supplemental Fig. 1) and shares similarities with 2 previous studies (1992 and 2004) conducted in Nunavik, northern Quebec, Canada (25,26). Inuit adults aged ≥18 y from households in 36 communities in the ISR (n = 6), Nunavut (n = 25), and Nunatsiavut (n = 6) were invited to participate in the survey. The survey assessed household overcrowding, food insecurity, chronic disease risk, diet and nutrition, physical activity, mental health, and blood concentrations of contaminants; the work described herein focuses exclusively on the contaminant, diet, and nutrition data. Evaluations of the other endpoints are presented elsewhere (25,27–31).

All work was approved by the research ethics boards of the University of Northern British Columbia, McGill University, and the Nunatsiavut Government research advisory committee. Also, all work was approved by community corporations (ISR) and hamlets (Nunavut) through community-research agreements. Research licenses were obtained from the Aurora Research Institute and Nunavut Research Institute. Before participating in the survey, individuals were required to read an informed consent form or view an informational DVD prior to signing an informed consent. The DVD and all documents and interviews were offered in both Inuktitut and English. A total of 2595 Inuit from the ISR, Nunavut, and Nunatsiavut aged ≥18 y participated in the survey; however, not all participants completed each part of the study. Of the 2595 participants, 2172 provided blood samples for the measurement of blood Hg, Se, EPA, and DHA and 2072 of those reported consuming traditional food during the previous 12 mo.

Traditional food consumption by participants over the preceding 12 mo was assessed by using a face-to-face administered FFQ, which was described in detail and validated with blood concentrations of nutrients and contaminants elsewhere (29,30,32). Store-bought foods were not within the scope of the FFQ. The list of traditional foods included in the questionnaire was based on the Centre for Indigenous Peoples’ Nutrition and Environment’s Inuit traditional FFQ, which was revised through consultation with the IHS Steering Committees of the ISR, Nunavut, and Nunatsiavut. Pictures of species were provided to ensure appropriate documentation. Due to excessive reporting of traditional food consumption, all intakes >90th percentile were reassigned to the 90th percentile (Supplemental Table 1).

Blood analysis. Blood concentrations of Hg and Se were measured to provide an accurate snapshot of total Hg and Se exposure for IHS participants. These blood concentrations may be considered more reliable estimates of exposure (in comparison to intake estimates) because they incorporate exposure from nontraditional food sources (e.g., store-bought foods, occupational exposure, dental amalgam) and are not contingent on the large uncertainty associated with recalling food consumption from the previous year. Blood was collected into plastic BD vacutainer tubes (Fisher Scientific) coated with K2-EDTA for whole blood and RBCs (29,33), and samples were stored at −80°C until analysis. Analyses were performed at the Laboratoire de Toxicologie of the Institut National de Santé Publique du Québec [ISO (International Organization for Standardization) accreditation 17025], which participates in the quality-assurance quality-control programs of the German External Quality Assessment Scheme and the Quebec Multi-element External Quality Assessment Scheme. An Elan DRC II (Perkin-Elmer) inductively coupled plasma–mass spectrometer was used for measuring Hg and Se in whole blood. The limits of detection for Hg and Se were 0.062 and 0.21 nmol/L, respectively. The between-day CVs were 3.7 and 3.8% for Hg and Se, respectively.

Concentrations of fatty acids in RBCs were measured by using GLC according to previously detailed procedures (33) at the Lipid Analytical Laboratories, University of Guelph Research Park. RBC phospholipid fatty acids were expressed as a percentage of total fatty acids. Lipid extraction was performed by using a previously defined protocol (34).

Metal concentrations in traditional foods. Mean Hg concentrations were extracted from a previously compiled contaminant database for traditional foods (35) and other sources (36–40). The database was updated in 2005, 2007, and 2008. This database of Hg concentrations is summarized in Supplemental Table 2. For each food with Hg concentrations that differed between the 3 participating regions, the arithmetic mean was used. A small number of traditional foods were not available for chemical analysis at the time of the survey. For each of these foods, Hg concentrations from surrogate food items that were available were used. The CV for each Hg concentration was assumed to be 100%, and the distributions were assumed to be log-normal. The Hg concentrations used to estimate the Hg intake of study participants relied on total Hg data (i.e., sum of inorganic Hg11 and methylmercury). Therefore, the Hg dietary intake estimates calculated herein do not account for speciation and bioavailability differences between and within food types.

Selenium and LC n3 fatty acid concentrations in traditional foods were compiled by using data obtained from peer-reviewed articles (39–43), the Canadian Arctic Contaminants Assessment Report II (44), and Canadian (45), U.S. (46), and U.K. (47) government databases. In total, the database contains weighted mean Se, EPA, and DHA concentrations reflecting the composition of 3489, 534, and 556 discrete food samples, respectively. These nutrient databases describing the concentrations of Se, EPA, and DHA in traditional foods are summarized in Supplemental Table 2. Nutrient concentrations could not be located for a small number...
of traditional foods in the survey; for each of these foods, estimated nutrient concentrations were based on measurements of surrogate food items.

**Statistical analyses.** A series of dietary intake models were constructed by using Crystal Ball software (Fusion Edition, version 11.1.1.1; Oracle) to estimate the Hg and nutrient intakes for survey participants. In addition, the models evaluated the percentage that each food contributed to participants Hg, Se, EPA, and DHA intake. The models included all participants (n = 2072) who reported consumption of at least 1 of the 82 traditional foods. The 329 input variables in the model included the following: 1) food (g · wk⁻¹) intake rate for each food (g food/wk), 2) Hg concentration in each food (µg Hg/g food), 3) Se concentration in each food (µg Se/g food), 4) EPA concentration in each food (g EPA/g food), 5) DHA concentration in each food (g DHA/g food), and 6) participant body weight. Sex was not included as an input variable; however, each iteration included a dummy identification value which enabled results to be summarized according to age, sex, and region. The results described herein pool data across age groups, sex, and regions. Participant (g) body weight and consumption rates were sampled sequentially from the FFQ, whereas Hg, Se, EPA, and DHA concentrations were randomly sampled from the log-normal distributions defined in Supplemental Table 2.

The 497 forecast variables in the model included the following: 1) total traditional food intake (g · wk⁻¹) for each participant, (Eq. 1), 2) percentage of total intake for each food, (Eq. 2), 3) mercury intake (µg · kg⁻¹ · wk⁻¹) from each food, (Eq. 3), 4) selenium intake (µg · kg⁻¹ · wk⁻¹) from each food, (Eq. 4), 5) EPA intake (g · wk⁻¹) from each food, (Eq. 5), 6) DHA intake (g · wk⁻¹) from each food, (Eq. 6), and 7) Se Health Benefit Value (HBV) for each food, (Eq. 7) (48,49). The mathematical equations that define each of these forecast variables are listed below:

\[
\text{Total traditional Food Intake}_i = \sum_{k=1}^{n_f} \text{food}_i \times \text{rate}_k \quad (\text{Eq. 1})
\]

\[
\text{Percent of Total Food Intake}_i = \frac{\text{food}_i \times \text{rate}_k}{\text{Total Food Intake}(g \cdot wk^{-1})} \times 100
\]

\[
\text{Hg Intake}_i = \frac{\text{food}_i \times \text{rate}_k \times \text{Hg}_i}{\text{Body Weight}(kg)} \quad (\text{Eq. 3})
\]

\[
\text{Se Intake}_i = \frac{\text{food}_i \times \text{rate}_k \times \text{Se}_i}{\text{Body Weight}(kg)} \quad (\text{Eq. 4})
\]

\[
\text{EPA Intake}_i = \frac{\text{food}_i \times \text{rate}_k \times \text{EPA}_i}{\text{g} \cdot \text{wk}^{-1}} \quad (\text{Eq. 5})
\]

\[
\text{DHA Intake}_i = \frac{\text{food}_i \times \text{rate}_k \times \text{DHA}_i}{\text{g} \cdot \text{wk}^{-1}} \quad (\text{Eq. 6})
\]

\[
\text{Se HBV}_i = \left( \frac{\text{Se}_i \times [\text{µmol} \cdot \text{kg}^{-1}] \times \text{Hg}_i \times [\text{µmol} \cdot \text{kg}^{-1}]}{\text{body weight}(kg)} \right) \quad (\text{Eq. 7})
\]

Foods with positive Se HBVs are thought to be a net health benefit by providing sufficient Se to offset the health risks from Hg, whereas foods with negative Se HBVs may be a net health risk because they do not offer sufficient Se to offset Hg risk (49). Ten Monte-Carlo simulations were completed for each of the 2074 IHS participants yielding 20,740 iterations for each input and forecast variable. Summary statistics (e.g., mean, SD, minimum, maximum, skewness, and kurtosis) were computed for each variable. In addition, the 10th, 20th, 50th, 80th, and 90th percentiles were calculated. Thereafter, percentages of participants who were above the TRV for Hg (50), outside the Acceptable Range of Oral Intake for Se (51), below the Adequate Intake (AI) for EPA (52), and below the AI for DHA (52) were calculated. Values are reported as means ± SDs or means ± SEMs.

**Validation of dietary intake model.** Blood Hg and Se and RBC EPA and DHA are reported to test the assumption that traditional food consumption is the primary contributor to Hg exposure and to Se, EPA, and DHA intake. We evaluated the extent to which the estimated nutrient intakes correlated with blood Hg and Se and RBC EPA and DHA. To this end, intake and blood concentration variables were log-transformed and then correlations were tested according to the Spearman rank test by using SigmaPlot (version 12; Systat Software). Correlations were considered significant when P < 0.05.

**Results**

Demographic and blood analysis data for IHS 2007–2008 participants are reported in Table 1. Estimated Hg dietary intake according to the Monte-Carlo simulations of the Crystal Ball model was correlated to the measured Hg blood concentrations of IHS participants (Table 2). Similarly, estimated intakes of Se...
HBVs >0.0 and 38% of the foods had Se HBVs >100 (excellent source of Se. Interestingly, 94% of the 82 traditional foods were all significantly correlated to their respective blood concentrations. Surprisingly, the correlations between estimated Hg intake and blood concentrations of Se, EPA, and DHA were stronger than the correlations observed between Se, EPA, and DHA intakes and their respective biomarker. Although speculative, this may indicate that the assumption of concentration normality used in the Crystal Ball model may be violated for Se, EPA, and DHA.

Overall, the arithmetic mean of Hg dietary intake of all 2074 participants was 7.9 \( \mu g \cdot kg^{-1} \cdot wk^{-1} \), with 35% of participants exceeding the Health Canada TRV of 5 \( \mu g \cdot kg^{-1} \cdot wk^{-1} \) (Table 3). The primary traditional food sources of Hg identified by the Monte-Carlo simulations are listed in Table 4, with the single largest traditional food source of Hg being ringed seal liver (59.1%). Ringed seal liver, with a mean Se HBV of 437, is also an excellent source of Se. Interestingly, 94% of the 82 traditional foods included in the Monte-Carlo analyses demonstrated Se HBVs >0.0 and 38% of the foods had Se HBVs >100 (Supplemental Table 3). All of the major Hg sources for participants of the IHS had positive Se HBVs. Of the 722 participants who exceeded the Hg TRV, 95.3% also met the AI/RDA for Se, EPA, and DHA. As such, each of the primary traditional food sources of Se (beluga muktuk), EPA (Arctic char), and DHA (Arctic char) were also within the top 3 sources of Hg (Supplemental Table 4). Accordingly, dietary nutrient intake was strongly correlated with dietary Hg intake, with Spearman correlation coefficients ranging between 0.81 (DHA; \( P < 0.001 \)) and 0.92 (Se; \( P < 0.001 \)) (Fig. 1).

Ringed seal liver was a major Hg contributor despite only providing 19, 0.9, and 0.5% of Se, EPA, and DHA intake, respectively (Table 4). The high contribution of ringed seal liver to Hg intake is especially remarkable when one considers the small quantities of ringed seal liver consumed by most Inuit (90th percentile: 71.8 g \cdot wk^{-1}). In contrast, the 90th percentile of Arctic char consumption is 1240 g \cdot wk^{-1}, but Arctic char only results in 8.4% of estimated Hg intake. These results underline the fact that, despite its Se HBV, ringed seal liver disproportionately elevates Hg intake relative to nutrient intake. Therefore, additional Monte-Carlo simulations were performed to evaluate what the dietary intakes of Hg, Se, EPA, and DHA would be if ringed seal meat, ringed seal blubber, beluga muktuk, or Arctic

### TABLE 4

Ten largest dietary sources of Hg, and the nutrient contribution of these foods, for 2074 participants of the International Polar Year Inuit Health Survey 2007–2008

<table>
<thead>
<tr>
<th>Food item</th>
<th>Hg ( \mu g \cdot kg^{-1} \cdot wk^{-1} )</th>
<th>Se ( \mu g \cdot kg^{-1} \cdot wk^{-1} )</th>
<th>EPA ( mg/wk )</th>
<th>DHA ( mg/wk )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ringed seal liver</td>
<td>32.7</td>
<td>4.7</td>
<td>59</td>
<td>3.8</td>
</tr>
<tr>
<td>Arctic char meat</td>
<td>378</td>
<td>0.67</td>
<td>8.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Beluga muktuk [skin only]</td>
<td>50.2</td>
<td>0.35</td>
<td>4.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Beluga muktuk [skin + fat]</td>
<td>76.7</td>
<td>0.33</td>
<td>4.1</td>
<td>4.0</td>
</tr>
<tr>
<td>Ringed seal meat</td>
<td>148</td>
<td>0.31</td>
<td>4.0</td>
<td>0.92</td>
</tr>
<tr>
<td>Caribou meat</td>
<td>731</td>
<td>0.30</td>
<td>3.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Narwhal muktuk [skin + fat]</td>
<td>31.2</td>
<td>0.16</td>
<td>2.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Dried caribou meat</td>
<td>269</td>
<td>0.13</td>
<td>1.6</td>
<td>0.035</td>
</tr>
<tr>
<td>Narwhal muktuk [skin only]</td>
<td>19.5</td>
<td>0.12</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Beluga meat</td>
<td>25.3</td>
<td>0.092</td>
<td>1.2</td>
<td>0.15</td>
</tr>
</tbody>
</table>

1 \( n = 2074 \). Dietary intake estimates were generated with Monte-Carlo simulations by using Crystal Ball software (Oracle) using FFQ responses of study participants and food composition data.

2 Weekly consumption of each food by study participants. Values are arithmetic means.

3 Estimated intake from each food for Hg and each nutrient. Values are arithmetic means.

4 The proportion that each food contributes to the total intake estimate.

5 Muktuk not including subdermal fat.

6 Muktuk including subdermal fat.
appreciable change to the percentage of participants below the Acceptable Range of Oral Intake for Se (Fig. 2). The replacement of ringed seal liver with ringed seal blubber also lowered mean Hg intake (57%) while increasing EPA (25%) and DHA (24%) intakes.

**Discussion**

The IHS 2007–2008 results showed that Hg blood concentrations were positively correlated with Se blood concentrations ($r_s = 0.83$, $P < 0.001$). This correlation was stronger than reported for school-age Inuit children in Nunavik ($r = 0.63$, $P < 0.01$) (53). Furthermore, estimated Hg and Se intakes were highly correlated when based on past-year traditional food consumption (Fig. 1). Correlations between Hg, EPA, and DHA biomarkers with past-year dietary intakes observed in the current study (Table 2) are in agreement with NHANES, which found a correlation ($r = 0.66$, $P < 0.001$) between LC n3 fatty acid intake and dietary Hg intake from fish and shellfish (54).

Our results are also in agreement with the correlations observed between Hg, Se, and LC n3 fatty acids for the Inuit village of Salluit in Nunavik, Quebec (55). In contrast, the results of a cross-sectional study of lakeside (non-Inuit) communities in Quebec showed that Se exposure remained constant between fish intake quartiles despite a positive association between fish intake and blood Hg (56). Similarly, the IHS results were contrary to those of a recent case-control study that showed no association between Hg and Se exposure (57). Discrepancies between the results of the IHS and these 2 previous studies (56,57) are likely a function of the vastly different diets of the study populations.

The strong correlations between the estimated intakes of EPA and DHA with their respective RBC fatty acid percentage are similar to those observed in intakes of pregnant women in Massachusetts (EPA: $r_s = 0.34$, $P < 0.001$; DHA: $r_s = 0.36; P < 0.001$) (58). These correlations were observed despite the contribution of endogenous LC n3 production to the biomarker data. Furthermore, biomarker EPA and DHA data reflect food consumption during the month before sampling, whereas estimated intake quantifies consumption over the previous year. It also should be noted that the correlation between estimated Hg intake and Hg blood concentration was similar to correlations observed in both a previous study in Inuit and Dene mothers living in Inuvik ($r_s = 0.55$, $n = 74$, $P < 0.001$) (1) as well as in NHANES participants ($r = 0.41$, $n = 3414$, $P < 0.001$) between 1999 and 2002 (54).

These similar correlation results were observed despite differences in tissue sampled (blood vs. hair). The kinetics of Hg elimination dictates that blood Hg best reflects recent exposure, whereas hair Hg levels integrate varying exposure levels over several months (59).

The fact that 38% of IHS participants had estimated Se intakes below the RDA of 5.1 µg · kg$^{-1}$ · wk$^{-1}$ (51) does not indicate that Inuit are selenium deficient. First, it is important to note that the nutrient intakes reported in this article were based solely on traditional food consumption and therefore do not include Se obtained from store-bought foods. In contrast, a total diet study in 1525 Inuit in Canada’s Arctic region showed that between 99 and 100% of participants met the DRI for selenium (60). Similarly, only 3 of the 2172 IHS participants had Se blood concentrations below the 1270-nmol/L plateau concentration associated with maximal plasma glutathione peroxidase activity (51,61); therefore, 99.9% of study participants had adequate concentrations of Se to prevent deficiency. Furthermore, comparing the 10th, 50th, and 90th percentiles of Se blood concentrations from the Canadian Health Measures Survey with those from the IHS...
shows that Inuit adults have consistently higher concentrations of Se than the general population of Canada, for which there is no evidence of Se deficiency (14). The Se intake estimates calculated by using Crystal Ball appeared to overestimate the percentage of participants at risk of selenosis (17%; Table 3). In contrast, only 4.3% of participants had blood Se concentrations above the guideline (12.7 μmol/L) associated with selenosis (51). However, it is not possible to determine whether these participants were adversely affected by excessive Se exposure because symptoms of selenosis (e.g., hair loss, nail sloughing) were not directly measured during the health examination.

Mean EPA and DHA intakes from traditional foods were 4.5- and 4.2-fold their respective AI values prescribed by the 1999 NIH workshop in Bethesda, MD (Table 3). These results are in agreement with those generated in the Inuit region of Nunavik where mean DHA blood concentrations were significantly greater than those in individuals following a typical Western diet (62). In contrast to the LC n3 fatty acid intake by Inuit, typical North American EPA and DHA intake values for adults (58,63) are approximately one-third of the AI recommended by the NIH (52). The richness of LC n3 fatty acids in the diet of Inuit is remarkable considering that the FFO data only included traditional foods and store-bought foods contribute substantially to the energy intake for most Inuit. These results underscore the nutrient density of traditional foods and the health benefits that Inuit receive through their consumption. For example, LC n3 fatty acids such as EPA and DHA, through a variety of mechanisms (e.g., channel protein binding, inhibition of proinflammatory cytokines, increased parasympathetic tone), may help the management of numerous medical conditions ranging from hypertension to inflammatory bowel disease to Alzheimer disease (64–67). In addition, numerous prospective and clinical studies have shown decreases in coronary heart disease with increasing LC n3 fatty acid intake (68,69), and recent work has demonstrated a potential link between LC n3 fatty acids and mental disorders (e.g., depression, anxiety) (70). Furthermore, EPA and DHA blood concentrations were significantly and positively associated with autonomic activity for Inuit women (but not men) in Nunavik (26). Maternal intake of DHA during pregnancy for Inuit in Nunavik significantly improved neurophysiologic and neurobehavioral endpoints in children (10–13 y of age) (53). Similarly, gestation period (and consequently birth weight) increased with increasing maternal DHA intake (62,71). DHA cord blood concentrations were also seen to be associated with an improvement in a variety of developmental (visual, physiologic) endpoints (62). These studies point to the following:

1. the importance of LC n3 to determinations of nutritional adequacy of adults,
2. long-lasting beneficial effect for infants and school-age children from maternal LC n3 fatty acid intake during pregnancy, and
3. reliance on traditional foods make Inuit one of the only subpopulations in North America to reach the suggested dietary targets (52,72) of EPA and DHA.

The mean estimated intake of Hg from traditional foods exceeds the Hg TRV (Table 3) and blood Hg concentrations of Inuit are elevated (Table 1); therefore, intervention through regional food advisories may prove necessary to lessen exposure to Hg. Additional details regarding Hg intake and concentrations are available in our study (50,51).

FIGURE 2 The effects of substituting current ringed seal liver intake with other traditional foods on the estimated intakes of Hg (A), Se (B), EPA (C), and DHA (D). Intake estimates were generated with Monte-Carlo simulations by using Crystal Ball software (Oracle) for all Inuit Health Survey participants (n = 2074). Estimated intake values (y-axes on left side of panels) represent the means ± SEMs, whereas the right-side y-axes define the percentage of participants who (A) exceed the Hg TRV of 5 μg · kg⁻¹ · wk⁻¹ (50), (B) fall within the Se AROI of 5.1–37 μg · kg⁻¹ · wk⁻¹ (51), (C) exceed the EPA AI of 1.5 g · wk⁻¹ (52), and (D) exceed the DHA AI of 1.5 g · wk⁻¹ (52). AI, Adequate Intake; AROI, Acceptable Range of Oral Intake; TRV, Toxicological Reference Value.
and health risk. However, estimated Hg intake was highly correlated to the estimated intakes of Se, EPA, and DHA (Fig. 1). Furthermore, biomarker concentrations of Hg, Se, EPA, and DHA showed the same trend (Table 2). These observations reflect the fact that several of the traditional foods that contribute to Hg intake by Inuit are also major sources of Se, EPA, and DHA. Therefore, wholesale reductions in traditional food consumption to limit Hg intake are likely to dramatically and negatively affect the nutrient intakes of Inuit. Consequently, it is vitally important that food advisories pertaining to the presence of Hg in traditional foods are designed to lower Hg exposure while minimizing adverse effects on Inuit nutrient intake and status. In addition, traditional foods are important sources of several macro- and micronutrients (e.g., protein, Fe, Zn, and vitamins A, D, and E) not included in the Crystal Ball model presented herein. Consequently, the statistics presented here do not capture the full suite of nutritional benefits that traditional foods offer Inuit. Risk communication efforts regarding the statistics presented herein. Consequently, the statistics presented here do not capture the full suite of nutritional benefits that traditional foods offer Inuit. Risk communication efforts regarding the presence of environmental contaminants must be designed to first, emphasize the healthfulness of traditional foods, and second, to prevent concomitant harm to the nutrient intakes of Inuit in Canada’s Arctic. As seen in Figure 2, the substitution of ringed seal liver with ringed seal meat, ringed seal blubber, beluga muktuk, or Arctic char represent 4 such strategies that decrease Hg intake without adversely affecting the nutrient intakes of Inuit. However, it is critical to note that these interventions may prove to be relevant for only specific regions and/or subpopulations and should not be construed as a wholesale recommendation for Inuit. Instead, communication and intervention strategies should be designed at the regional level to ensure that they are relevant to the varying exposure levels and sources present for the 3 participating regions of the IHS. The lessons learned from this comprehensive benefits and risks assessment can be applied to other indigenous populations globally. Public health agencies and local health authorities need to develop dietary advisories to lower the risk of contaminant intake without jeopardizing the nutritional quality of their populations.

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