Traditional Food Intake Is Correlated with Iron Stores in Canadian Inuit Men\textsuperscript{1,2}

Jennifer A. Jamieson\textsuperscript{3–5*}, Hope A. Weiler\textsuperscript{4}, Harriet V. Kuhnlein\textsuperscript{3,4} and Grace M. Egeland\textsuperscript{3,4*}

\textsuperscript{3}Centre for Indigenous Peoples’ Nutrition and Environment, and \textsuperscript{4}School of Dietetics and Human Nutrition, McGill University, Montreal, Canada

Abstract

Accelerated loss of traditional lifestyles may place Inuit at risk of iron depletion given that anemia has been observed among Arctic men. The objectives of this study were to determine the prevalence of anemia, storage iron depletion, and iron overload and to identify correlates of iron status in Canadian Inuit men. In a cross-sectional survey of 994 men in the International Polar Year Inuit Health Survey, 2007–2008, hemoglobin, serum ferritin (SF), soluble transferrin receptor (on a subset), CRP, RBC fatty acid composition, and Helicobacter pylori serology were measured in venous blood drawn from fasting men. Anthropometric, dietary, sociodemographic, and health data were collected. Dietary and nondietary correlates of iron status were assessed with multiple linear and logistic models. For men with CRP ≥10 mg/L (n = 804), 6.5% had depleted, 19.8% had low, and 10.3% had elevated iron stores. Anemia was moderately prevalent (16.1%), but iron deficiency anemia was less common (2.4%). There was a low probability of dietary iron inadequacy (2.4% < Estimated Average Requirement) and excess iron intakes (10.7% > Tolerable Upper Intake Level). Those with CRP ≥10 mg/L were less likely to have depleted iron stores (4.8% vs. 7.7%) and a higher rate of anemic iron stores (20% vs. 15%). Low transferrin saturation (<20%) and a high rate of anemia (28–48%) (2). However, a subanalysis on this sample reported ≤1% of men with depleted iron stores (SF <15 μg/L) (3). The 1993–1994 Greenland Inuit survey (n = 224) reported low rates of both ID and anemia (<4%), but up to 32% of men in a traditional community had elevated iron stores (4,5). In the Alaskan and Canadian surveys, anemia rates tended to increase with age, whereas ID decreased with age.

Changing lifestyle and dietary patterns among Arctic indigenous peoples include less reliance on TF, a well-documented characteristic of the nutrition transition. For Inuit, this transition exists most strongly in younger Inuit, whereas high TF use continues predominantly among elders (6,7). Traditional Inuit foods are largely animal-based and excellent sources of bioavailable iron (7). Whether reduced intakes of TF may be responsible for low iron status indices or if other endemic factors may contribute to ID and anemia among Inuit men have not been thoroughly investigated.

Adequacy of dietary iron intake among Arctic indigenous peoples has been demonstrated (1,8) but is in contradiction with previous biochemical surveys (1,2). However, among Inuit preschoolers, high dietary iron intake was recently observed with low rates of IDA and ID (9,10). In Greenland, 98% of Inuit men had SF ≥20 μg/L, but there was regional variation (4). The most traditional Greenlandic community had a higher median

Introduction

ID\textsuperscript{6} and anemia are rare among men residing outside of areas where malaria, Schistosoma, and hookworm are endemic. Over the past several decades, higher than expected rates of ID and anemia have been observed among Arctic indigenous men despite a traditional diet rich in animal-source foods and lack of parasitic explanation. Prevalence rates, however, vary considerably by Arctic region. Surveys of Alaskan natives (n = 2024) from 1988–1989 found that up to 10% of men were ID and 15% anemic (1). The 1976 Nutrition Canada Survey (n = 346) observed a substantial proportion of Inuit men (24–38%) with low transferrin saturation (<20%) and a high rate of anemia (28–48%) (2). However, a subanalysis on this sample reported ≤1% of men with depleted iron stores (SF <15 μg/L) (3). The 1993–1994 Greenland Inuit survey (n = 224) reported low rates of both ID and anemia (<4%), but up to 32% of men in a traditional community had elevated iron stores (4,5). In the Alaskan and Canadian surveys, anemia rates tended to increase with age, whereas ID decreased with age.

Changing lifestyle and dietary patterns among Arctic indigenous peoples include less reliance on TF, a well-documented characteristic of the nutrition transition. For Inuit, this transition exists most strongly in younger Inuit, whereas high TF use continues predominantly among elders (6,7). Traditional Inuit foods are largely animal-based and excellent sources of bioavailable iron (7). Whether reduced intakes of TF may be responsible for low iron status indices or if other endemic factors may contribute to ID and anemia among Inuit men have not been thoroughly investigated.

Adequacy of dietary iron intake among Arctic indigenous peoples has been demonstrated (1,8) but is in contradiction with previous biochemical surveys (1,2). However, among Inuit preschoolers, high dietary iron intake was recently observed with low rates of IDA and ID (9,10). In Greenland, 98% of Inuit men had SF ≥20 μg/L, but there was regional variation (4). The most traditional Greenlandic community had a higher median
SF (118 μg/L) than the most westernized community (92 μg/L) and SF was reasonably correlated (R = 0.26; P = 0.01) with TF intake (4). Therefore, accelerated loss of traditional lifestyles may place Inuit at heightened risk of iron depletion.

Other factors endemic to the Arctic that might relate to iron status include a high prevalence of household food insecurity as observed in homes with children (69.6%) in the Canadian territory of Nunavut (11), where there are barriers in TF acquisition and access to healthy market foods (12). Additionally, Helicobacter pylori infection is associated with decreased SF and/or increased risk of IDA in some populations (13–16), likely through multiple mechanisms, including bacterial iron utilization, decreased gastric acidity leading to impaired iron absorption, and increased iron losses through gastric micro-bleeding (13). H. pylori infection may, therefore, impair iron status of Inuit, which appears modest despite potentially abundant heme iron intake (17). Finally, inflammation affects nutritional status indicators, including SF. Inuit are at increased risk for tuberculosis, pneumonia, hepatitis, and food-borne pathogens such as Trichinella compared to national risk statistics (18). Inadequate housing sanitation, water supply, and overcrowded conditions are thought to contribute to the high rates of infectious disease for Inuit (19). Previous biochemical surveys have not accounted for the impact of infections and inflammation and may therefore have underestimated the prevalence of ID in the past.

The objectives of this study were to determine the prevalence of anemia, depletion of iron stores, and iron overload to identify correlates of iron status in a representative sample of Canadian Inuit men from ISR, Nunavut Territory, and Nunatsiavut of Northern Labrador.

Methods

Survey design. A cross-sectional Inuit health survey of adults was conducted in the summer and fall of 2007–2008 in 36 Arctic communities across ISR, Nunavut, and Nunatsiavut, as previously described (20). The sample was stratified by community with households randomly selected from each community. Of the 2796 Inuit households approached, 1901 households (68%) agreed to participate, with a total of 2595 adult participants, of whom 38.5% were male. Fasting venous blood samples, anthropometric measurements, a 24-h dietary recall, a semiquantitative FFQ, and five general questionnaires were administered either on-land or upon the Canadian Coast Guard Ship Amundsen. Venous blood samples were obtained from 880 (88.2%) men, of whom 852 had both a SF and a hs-CRP test result. Iron status for Inuit women is reported separately because of the magnitude of the dataset and different inter-relationships among variables, which become obscured when combined into one dataset. Ethical approval for the study was obtained from the McGill University Faculty of Medicine Institutional Review Board and appropriate territorial research licenses were acquired. The survey was guided through a participatory process (20).

Clinical assessment. Weight and body composition were measured using bioelectrical impedance analysis (Tanita TBF-300GS). Height was measured with a portable stadiometer (Road Rod 214) to the nearest millimeter. Normal weight, overweight, and obesity were defined by the WHO classification system (21). At-risk percent body fat was defined as >20, >22, and >25% for ages 18–39, 40–59, and ≥60 y, respectively. Fasting venous blood was collected in SST vacutainer tubes with clot activator and polymer gel for serum separation (Becton Dickinson) or EDTA-coated vacutainers for plasma and whole blood hematology (Becton Dickinson). Hemoglobin measures were obtained from venous blood drops or blood drops from a finger prick using the azidenethemoglobin method with HemoCue 201+ portable photometer (HemoCue) due to survey logistics. Hemoglobin values were adjusted for cigarette smoking according to WHO protocols (22). Prevalence estimates of anemia were based on venous samples only and classified according to the WHO 130-μL cutoff for adult men (22). IDA was defined as anemia + SF <15 μg/L or ferritin 15–50 μg/L + hs-CRP >10 mg/L.

Laboratory analyses. Iron status was determined in serum by ferritin, hs-CRP, and, for a subsample (n = 387), sTfR. SF was measured at McGill University using an automated chemiluminescence assay (Liaison Ferritin) with a detection limit of 0.5 μg/L. hs-CRP was measured using an automated analyzer (Beckman Coulter) with a 0.2-mg/L limit of detection at the Montreal General Hospital. Due to high cost of the assay, the sTfR concentration was analyzed as a secondary marker of iron status on a subsample by ELISA (R&D Systems) at McGill University on a Synergy HT microplate reader (BioTek). The subsample included participants from all 3 regions but only samples collected in 2008, because sTfR is stable for 1 y at −80°C, according to the manufacturer. The limit of detection for the assay was 0.225 mg/L. Iron status was evaluated by the amount of storage iron as well as functional tissue deficiency. sTfR >2.75 mg/L was considered iron-deficient erythropoiesis, as suggested by the manufacturer. Depleted iron stores was defined by SF <15 μg/L or SF = 15–50 μg/L in the presence of acute inflammation (hs-CRP ≥10 mg/L). Low iron stores was defined as SF ≤32 μg/L and >14.9 μg/L in the absence of acute inflammation, because SF ≥32 μg/L reflects the presence of storable iron in the marrow and is considered an iron-replete state (4). SF >200 μg/L in the absence of acute inflammation was used to define elevated iron stores to compare to other studies of Inuit populations (4), with age-appropriate cutoffs for iron overload utilized by NHANES (23) also determined. Immunoenzymatic methods (ELISA) were used to detect IgG antibodies against H. pylori in serum (Calbiotech) at the Montreal General Hospital. Fatty acid composition was analyzed on RBC membranes (Lipid Analytical Laboratories), with lipid extraction based on the methodology of Folch et al. (24). The FAME were prepared by standard techniques (25) and analyzed on a Varian 3400 gas-liquid chromatograph (Palo Alto) with a 60-m DB-23 capillary column (0.32 diameter). Total EPA and DHA were expressed as percent of total fatty acids and will hereafter be referred to as LC-PUFA.

Dietary assessment. Dietary intake data were collected by trained interviewers using a single 24-h recall with a 4-stage, multi-pass approach (26). Portion sizes were estimated with a graduated, 3-dimensional food model kit (Santé Québec). Recall data were entered into CANDAT software (Godin London) and nutrient analyses obtained from the 2007th CNF, a database containing foods not available on the CNF, recipes, information from food labels, and data from an indigenous food nutrient file developed by the Centre for Indigenous Peoples’ Nutrition and Environment, and an additional database of imputed values for nutrients missing in the CNF housed at the School of Dietetics and Human Nutrition (McGill University). There were no missing values for the foods and nutrients included in the analysis. Recall data were available for 805 male participants after 25 recalls were excluded due to incompleteness. Dietary iron adequacy was assessed by the EAR cutpoint method using SIDE software (27), in which within-subject variation estimates for iron intake were obtained from previous Centre for Indigenous Peoples’ Nutrition and Environment dietary surveys with Canadian Inuit populations (6). Nutrient CV were available for Inuit <40 and ≥40 y of age. Median nutrient intakes were analyzed for men from the 24-h recall and compared to the EAR of select nutrients. Eighteen-year olds (n = 18) were excluded from this intake analysis due to different DRI requirements for their age group. Nutritional supplement and medication use were documented in a questionnaire administered by a nurse, for which participants were asked to bring containers of supplements and medicines taken to their appointment for accurate recording. Supplement content was not included in the nutrient analysis of the 24-h recalls, because most supplement users could not recall the brand or amount of supplement taken. TF frequency data were available for 805 male participants. Frequency of TF use was recorded for in-season and off-season consumption of each item over the past 12 mo. Seasons were determined according to regional wildlife harvest calendars and intakes adjusted to frequency per month (assuming 30.4 d/mo).

Questionnaires. Questionnaires for sociodemographic, health, and household characteristics were adapted from Greenlandic and Nunavik (Canada) Inuit Health Surveys (28) and the Aboriginal Peoples Survey
(29) and through consultations with regional steering committees and key informants. The household questionnaire included a version of the 18-item USDA Household Food Security Survey Module (30); details of the questionnaire and classification of household food security are described elsewhere (11). A household food security score was dichotomized into secure or insecure for analyses. Marital status was dichotomized into single (including widowed, divorced, or separated) and married (including common-law marriage). Alcohol use was dichotomized by whether alcohol was consumed in the past year or not. Current smoking behavior was assessed as yes or no and further quantified by cigarettes per day. ASA use was dichotomized into either daily users or infrequent and nonusers to investigate chronic ASA use as a correlate of iron status.

Calculations and statistics. SF and sTfR concentrations were log_{10} transformed to improve normality of the respective distributions. Weighted prevalence estimates of iron status are given with 95% CI. Sampling weights reflected the proportion of participating men using Statistics Canada’s Census data of age-appropriate Inuit men by community. Age categories were based on the DRI recommendations for iron intake (31), although age groups 51–70 and ≥70 were combined due to small sample size among the elderly. Independent determinants of log_{10}SF were examined in a multivariable linear mixed regression model, with household and community as random effects. Variables known a priori or suspected to be related to iron status were selected and evaluated. The model was based on 803 men with SF available and hs-CRP ≤10 mg/L. Sample size limited interaction testing to only 2 × 2 interactions between main effects, but none were found. Independent determinants of elevated iron stores compared to good iron stores and low or depleted iron stores compared to good iron stores were assessed with multivariable logistic models. Two by two interactions were investigated but none observed. Model assumptions (normality of residuals and homoscedasticity) were confirmed graphically with standard procedures. All analyses were performed in STATA (version 11; StataCorp). P values were all 2-sided and significance was set at $P \leq 0.05$.

Results

Study population. The age of the men [mean ± SD (range)] was 42 ± 15 y (18–89 y), with 33% overweight and 27% obese by WHO criteria. Underweight was almost nonexistent (0.4% or 3 men). Sixty-eight percent currently smoked, with a median of 12 cigarettes/d (IQR: 7–17). Daily use of ASA (80–325 mg) and prescription or nonprescription medication use was reported by 4.9 and 36.3%, respectively. High blood pressure, diabetes mellitus, and high cholesterol were self-reported in 23, 6, and 10% of men, respectively, and a low rate of IDA and low rates of iron-deficient erythropoiesis. Overall, 63.5% were classified as iron replete ($SF = 32–200 \mu g/L$). Low or depleted iron stores were common (40.5%) among young men (18–30 y), but few were categorized with iron depletion. Prevalence of elevated iron stores was moderately high in men over 50 y (19.2%). Severe iron overload ($SF > 700 \mu g/L$) was present in only 2 men. When using age-appropriate cutoffs for iron overload (23), prevalence rates dropped to 1.6% (18–30 y), 4.2% (31–50 y), and 5.2% (≥51 y).

Median dietary iron intake (adjusted for within-subject variation and unadjusted values) exceeded both the EAR and RDA (Table 2). Median intakes of vitamin C, calcium, and vitamin A were less than EAR. Tea and coffee were consumed by 44.0 and 4.1%, respectively, of men on the day before the survey. Median intakes from carbohydrate, protein, and fat accounted for 45.5, 19.9, and 31.6% of energy, respectively. Across all age groups, there was a low probability of iron inadequacy, with 2.4% of adjusted intakes below the age-specific EAR. A small proportion of the sample (10.7%) had an adjusted iron intake above the DRI upper limit (45 mg/d). Daily frequency of consumption of TF species was highest for game, followed by sea mammals, fish, and birds. Liver consumption was infrequent (Table 2). In order of contribution, the top 5 sources of iron for men 19–50 y were: TF meats (28%), market food meats (12%), mixed foods with meat (12%), breads (9%), and cereals (4%). For men >50 y, the greatest iron sources were: TF meats (48%), market food meats (11%), breads (10%), bannock (6%), and cereals (5%).

Correlates of iron status. The SF concentration was positively correlated with percent energy as TF, TF meat, dietary iron from TF, hs-CRP, LC-PUFA, hemoglobin, and frequency of TF intake (including game and birds) (Table 2). The SF concentration was negatively associated with sTfR concentrations.

TABLE 1 Weighted prevalence of iron status and anemia among Inuit men (International Polar Year Inuit Health Survey, 2007–2008)\(^2\)

<table>
<thead>
<tr>
<th>Age, y</th>
<th>$n$</th>
<th>% (95% CI)</th>
<th>$n$</th>
<th>% (95% CI)</th>
<th>$n$</th>
<th>% (95% CI)</th>
<th>$n$</th>
<th>% (95% CI)</th>
<th>$n$</th>
<th>% (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18–30</td>
<td>99</td>
<td>6.4 (3.0–13.0)</td>
<td>196</td>
<td>9.9 (5.6–16.8)</td>
<td>196</td>
<td>30.7 (23.5–38.9)</td>
<td>196</td>
<td>1.6 (0.5–5.1)</td>
<td>96</td>
<td>2.7 (0.9–8.0)</td>
</tr>
<tr>
<td>31–50</td>
<td>220</td>
<td>10.6 (6.7–16.2)</td>
<td>386</td>
<td>6.3 (4.1–9.6)</td>
<td>386</td>
<td>22.7 (17.9–28.3)</td>
<td>386</td>
<td>8.4 (5.1–13.5)</td>
<td>213</td>
<td>3.2 (1.4–7.5)</td>
</tr>
<tr>
<td>51</td>
<td>135</td>
<td>30.3 (22.1–40.0)</td>
<td>232</td>
<td>4.2 (2.0–8.4)</td>
<td>232</td>
<td>7.7 (5.0–11.7)</td>
<td>232</td>
<td>19.2 (12.9–27.8)</td>
<td>119</td>
<td>1.1 (0.2–4.6)</td>
</tr>
<tr>
<td>Total</td>
<td>454</td>
<td>16.1 (12.5–20.6)</td>
<td>814</td>
<td>6.5 (4.8–8.7)</td>
<td>814</td>
<td>19.8 (16.7–23.2)</td>
<td>814</td>
<td>10.3 (7.5–13.9)</td>
<td>428</td>
<td>2.4 (1.3–4.5)</td>
</tr>
</tbody>
</table>

Where anemia = hemoglobin < 130 g/L; depleted iron stores = $SF < 15 \mu g/L$ or ferritin $15–50 \mu g/L + CRP > 10 \mu g/L$; low iron stores = ferritin $15–32 \mu g/L + CRP ≤ 10 \mu g/L$; elevated iron stores = ferritin $> 200 \mu g/L + CRP ≤ 10 \mu g/L$; IDA = depleted iron stores + anemic; iron-deficient erythropoiesis = serum sTfR > 2.75 mg/L. $SF$, serum ferritin; sTfR, soluble transferrin receptor.

\(^2\) Analyses on a subset with venous blood sampling for hemoglobin determination.

\(^3\) Analyses on a subset with sTfR measurements.
marital status, and H. pylori infection were negatively associated with SF. Daily ASA use and tea on the previous day were marginally significant in the model ($P \leq 0.1$). The model explained 28% of the variation ($R^2 = 0.28$) in log$_{10}$SF. In a multivariate-adjusted logistic model ($R^2 = 0.12$), food insecurity and having no hunter in the home were associated with increased risk of low or depleted iron stores (SF 32–200 μg/L) (Table 4). At-risk body fat percent and elevated hs-CRP were associated with reduced risks of low or depleted iron stores. TF on the previous day and tea on the previous day were marginally significant in the model ($P \leq 0.1$). In a multivariate-adjusted logistic model ($R^2 = 0.12$), food insecurity and having no hunter in the home were associated with increased risk of low or depleted iron stores (SF 32–200 μg/L) (Table 4). At-risk body fat percent and elevated hs-CRP were associated with reduced risks of low or depleted iron stores. 

A multivariate-adjusted logistic model ($R^2 = 0.23$) showed that increased age and at-risk percent body fat were associated with increased risk of low or depleted iron stores. Food insecurity, smoking, and H. pylori infection were negatively associated with reduced risks of low or depleted iron stores. Single marital status, daily ASA use, tea on the previous day, and lack of a hunter at home were marginally ($P \leq 0.1$) associated with a lower risk.

**Discussion**

This is the first representative survey to our knowledge to report prevalence estimates of anemia and depleted iron stores for Inuit men in Canada. Anemia was moderately prevalent, with the highest rates observed among those >50 y. Although low iron stores were common, iron depletion and IDA were infrequent and corresponded with a low prevalence of dietary iron inadequacy. If good iron status is defined by the minimal amount of iron stores to meet requirements (SF = 15 μg/L), the DRI criteria, then >93% of Inuit men would have adequate iron stores. Indeed, there is no reported benefit of having excess iron stores (31) and SF >50 μg/L is correlated with increased risk of vascular disease (32). Nonetheless, iron status is lower than would be expected from a diet with abundant heme iron. Limited iron storage may be an evolutionary adaption to prevent infectious disease (33) or an adaptation to a traditional diet rich in heme iron. Anemia estimates are consistent with previous studies in Canada (3) and Alaska (1) but higher than the Greenland rate (3.5%) reported in 1993–1994 (5). Of note, anemia estimates were consistently higher among older men and mainly occurred in those with adequate iron stores, suggesting a nondietary iron etiology. Prevalence of iron depletion reported here is similar to previous Alaska Native surveys (4–10%) (1) but higher than reported by a previous Canadian survey (<1%) (3) and the Greenlandic Inuit survey (0–4%) (4). Similarly, median SF (Table 2) was considerably lower in the current study than observed in the Greenlandic communities (92–118 μg/L) but higher than Alaska Native estimates (38 μg/L). It is unknown at this time if these differences reflect differences in TF use, failure to assess the impact of inflammation on iron status, other risk factors, or temporal changes associated with the nutrition

**TABLE 2** Correlations between dietary variables and SF for Inuit men (International Polar Year Inuit Health Survey, 2007–2008)$^1$

<table>
<thead>
<tr>
<th>Dietary Variable</th>
<th>n</th>
<th>Spearman’s $\rho$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous day’s intake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy, MJ</td>
<td>739</td>
<td>9.06 (6.04–12.8)</td>
</tr>
<tr>
<td>TF, % energy</td>
<td>739</td>
<td>9.8 (0.0–34)</td>
</tr>
<tr>
<td>TF meat, g</td>
<td>739</td>
<td>147 (0–421)</td>
</tr>
<tr>
<td>All meat, g</td>
<td>739</td>
<td>353 (164–653)</td>
</tr>
<tr>
<td>Unadjusted dietary iron, mg</td>
<td>739</td>
<td>16.6 (10.1–28.2)</td>
</tr>
<tr>
<td>Adjusted dietary iron, mg</td>
<td>739</td>
<td>20.2 (13.7–31.6)</td>
</tr>
<tr>
<td>Dietary iron from TF, mg</td>
<td>739</td>
<td>1.9 (0–16)</td>
</tr>
<tr>
<td>Dietary iron from nontraditional meats, mg</td>
<td>739</td>
<td>0.5 (0–2.6)</td>
</tr>
<tr>
<td>Heme iron, mg</td>
<td>739</td>
<td>6.3 (1.7–17.1)</td>
</tr>
<tr>
<td>Vitamin C, mg</td>
<td>739</td>
<td>61.8 (13.5–172)</td>
</tr>
<tr>
<td>Calcium, mg</td>
<td>739</td>
<td>441 (249–734)</td>
</tr>
<tr>
<td>Vitamin A, μg RAE</td>
<td>739</td>
<td>417 (145–870)</td>
</tr>
<tr>
<td>Tea, ml</td>
<td>739</td>
<td>0 (0–500)</td>
</tr>
<tr>
<td>Frequency of consumption, n/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All TF</td>
<td>738</td>
<td>0.74 (0.32–1.63)</td>
</tr>
<tr>
<td>Sea mammals</td>
<td>738</td>
<td>0.07 (0.01–0.29)</td>
</tr>
<tr>
<td>Game</td>
<td>738</td>
<td>0.29 (0.08–0.70)</td>
</tr>
<tr>
<td>Fish</td>
<td>738</td>
<td>0.11 (0.02–0.33)</td>
</tr>
<tr>
<td>Birds</td>
<td>738</td>
<td>0.02 (0.01–0.10)</td>
</tr>
<tr>
<td>Liver, all species</td>
<td>738</td>
<td>0.01 (0.0–0.10)</td>
</tr>
<tr>
<td>Iron status and other indicators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RBC, % total FA</td>
<td>810</td>
<td>3.7 (2.1–5.7)</td>
</tr>
<tr>
<td>Serum hs-C-reactive protein, mg/L</td>
<td>813</td>
<td>1.2 (0.5–2.9)</td>
</tr>
<tr>
<td>Hemoglobin, g/L</td>
<td>776</td>
<td>142 (131–152)</td>
</tr>
<tr>
<td>Serum sTfR, mg/L</td>
<td>366</td>
<td>1.27 (1.11–1.46)</td>
</tr>
<tr>
<td>SF, μg/L</td>
<td>803</td>
<td>55.9 (30.4–95.6)</td>
</tr>
</tbody>
</table>

$^1$ Values are median (IQR), $n = 803$. * $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$. SF, serum ferritin; TF, traditional food.
iron overload or chronic inflammation (36,37) and may explain
protein, is known to increase with adiposity because of either
of iron status based on SF in Inuit men. SF, an acute-phase
suggesting that continued TF use may explain iron status
of TF use) independent of other confounders (Table 3),
previous day as well as with percent LC-PUFA in RBC (a marker
Similarly, age and SF were correlated in Nunavut but not in the
between age and SF in a traditional community with higher TF
use compared to a more westernized community in Greenland.
TF intake rather than a potential genetic difference in iron absorption
Inuit has been attributed to the lifelong intake of an iron-rich
diet rather than a potential genetic difference in iron absorption
(34). This is in contrast to Caucasian men, who show a
consistent plateau in SF by 30–35 y that is maintained until ≥70
y (32,34,35). This pattern of accumulation of iron stores for
people (75%) had hs-CRP values
3 mg/L, suggesting that the
high prevalence of obesity (27%) did not confound the assessment
of iron status.

**TABLE 3** Multiple linear regression coefficients for SF based on nondietary and dietary determinants as independent variables among Inuit men (International Polar Year Inuit Health Survey, 2007–2008)1–4

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate coefficient</th>
<th>SE</th>
<th>Multivariate coefficient</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1.76***</td>
<td>0.02</td>
<td>1.53***</td>
<td>0.08</td>
</tr>
<tr>
<td>Age, y</td>
<td>0.008***</td>
<td>&lt;0.001</td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>Body fat, %</td>
<td>0.018***</td>
<td>0.001</td>
<td>0.010***</td>
<td>0.002</td>
</tr>
<tr>
<td>Smoker (1 = yes, 0 = no)</td>
<td>-0.231***</td>
<td>0.028</td>
<td>-0.102**</td>
<td>0.031</td>
</tr>
<tr>
<td>Food insecure (1 = yes, 0 = no)</td>
<td>-0.174***</td>
<td>0.029</td>
<td>-0.104**</td>
<td>0.030</td>
</tr>
<tr>
<td>H. pylori (1 = yes, 0 = no)</td>
<td>-0.105**</td>
<td>0.031</td>
<td>-0.064*</td>
<td>0.030</td>
</tr>
<tr>
<td>Single marital status (1 = yes, 0 = no)</td>
<td>-0.159***</td>
<td>0.029</td>
<td>-0.064*</td>
<td>0.030</td>
</tr>
<tr>
<td>Daily ASA use (1 = yes, 0 = no)</td>
<td>0.060</td>
<td>0.067</td>
<td>-0.135</td>
<td>0.063</td>
</tr>
<tr>
<td>hs-CRP (1 = 3–10 mg/L, 0 = &lt;3 mg/L)</td>
<td>0.213***</td>
<td>0.032</td>
<td>0.138***</td>
<td>0.034</td>
</tr>
<tr>
<td>TF intake on previous day (1 = yes, 0 = no)</td>
<td>0.143***</td>
<td>0.028</td>
<td>0.083**</td>
<td>0.028</td>
</tr>
<tr>
<td>RBC (n-3) PUFA, % of total fatty acids</td>
<td>0.033***</td>
<td>0.005</td>
<td>0.014*</td>
<td>0.006</td>
</tr>
<tr>
<td>Tea intake on previous day (1 = yes, 0 = no)</td>
<td>0.048</td>
<td>0.030</td>
<td>-0.050</td>
<td>0.029</td>
</tr>
</tbody>
</table>

1 Analyses conducted on log10(SF, μg/L); n = 614. * P ≤ 0.05; ** P ≤ 0.01; ***P ≤ 0.001. ASA, acetylsalicylic acid; hs-CRP, high-sensitivity CRP; SF, serum ferritin; TF, traditional food.
2 The within-dwelling and within-community variance components were 0.03 and 2.0, respectively.
3 Participants with hs-CRP >10 mg/L were excluded to remove the effect of inflammation on SF.
4 All variables presented were evaluated together in one model.

transition. However, adjusting for hs-CRP had little impact on iron status assessment for this sample.
SF increased progressively with age in Inuit men (Fig. 1), similar to observations among Inuit and Alaska Native popu-
lations (1,34). This is in contrast to Caucasian men, who show a
consistent plateau in SF by 30–35 y that is maintained until ≥70
y (32,34,35). This pattern of accumulation of iron stores for
Inuit has been attributed to the lifelong intake of an iron-rich
diet rather than a potential genetic difference in iron absorption
(34). Milman et al. (4) were able to show a stronger correlation
between age and SF in a traditional community with higher TF
use compared to a more westernized community in Greenland.
Similarly, age and SF were correlated in Nunavut but not in the
less traditional regions of ISR and Nunatsiavut (data not shown).
We have also shown SF to increase with TF use on the
previous day as well as with percent LC-PUFA in RBC (a marker
of TF use) independent of other confounders (Table 3),
suggesting that continued TF use may explain iron status

differences.

To our knowledge, no studies have investigated determinants
of iron status based on SF in Inuit men. SF, an acute-phase
protein, is known to increase with adiposity because of either
iron overload or chronic inflammation (36,37) and may explain
the positive association observed between excess adiposity and
risk of iron depletion. Whether this relationship is a reflection of
how the biomarkers change in parallel or of true iron stores
requires further studies. Nonetheless, the majority of partici-
pants (75%) had hs-CRP values <3 mg/L, suggesting that the
high prevalence of obesity (27%) did not confound the assessment
of iron status.

TF was the most important dietary source of iron for men of
all ages. TF use and access (a hunter at home) were also related
to SF and adequate iron stores, demonstrating the importance of
these nutrient-dense foods. In particular, the proportion of RBC
as LC-PUFA remained positively associated with SF after
multivariate adjustment. Consumption of marine mammals
and fish are predictors of RBC LC-PUFA in our study popula-
tion, as also noted for Inuit in Northern Quebec (38). Therefore,
consumption of animal-source foods, including traditional
meats and fish, may explain the relationship between LC-
PUFA and SF. Marine mammals, second only to cereals and
pasta as an iron source for Alaska Natives (39), are rich sources
of iron, ranging from 17 mg/100 g raw food (walrus meat) to
57 mg/100 g dried food (beluga meat) (40). In comparison, raw
ground beef contains 1.8 mg iron/100 g (41).

**TABLE 4** Logistic regression coefficients, OR, and 95% CI with low or depleted iron stores as the dependent variable among Inuit men (International Polar Year Inuit Health Survey, 2007–2008)1–3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate OR</th>
<th>Multivariate OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>0.964***</td>
<td>0.982</td>
<td>0.963</td>
</tr>
<tr>
<td>Percent body fat &gt; cutoff (1 = yes, 0 = no)</td>
<td>0.189***</td>
<td>0.251***</td>
<td>0.120</td>
</tr>
<tr>
<td>Food insecure (1 = yes, 0 = no)</td>
<td>3.01**</td>
<td>2.33*</td>
<td>1.77</td>
</tr>
<tr>
<td>hs-CRP (1 = 3–10 mg/L, 0 = &lt;3 mg/L)</td>
<td>-1.53**</td>
<td>0.33**</td>
<td>0.14</td>
</tr>
<tr>
<td>Hunter in home (1 = no, 0 = yes)</td>
<td>1.70</td>
<td>2.06*</td>
<td>1.03</td>
</tr>
<tr>
<td>TF intake on previous day (1 = yes, 0 = no)</td>
<td>0.581*</td>
<td>0.634</td>
<td>0.366</td>
</tr>
<tr>
<td>Tea intake on previous day (1 = yes, 0 = no)</td>
<td>1.15</td>
<td>1.54*</td>
<td>0.90</td>
</tr>
</tbody>
</table>

1 The within-dwelling variance component was 2.0. * P ≤ 0.05; ** P ≤ 0.01; ***P ≤ 0.001. hs-CRP, high-sensitivity CRP; TF, traditional food.
2 Men with hs-CRP >10 mg/L and men with elevated iron stores were excluded from the model, n = 622.
3 For highly prevalent outcomes, the OR will tend to exaggerate the true RR.
Food insecurity was an independent determinant of extremes of iron stores (low or depleted and elevated iron stores) and SF concentrations. Food insecurity can result in consumption of less desirable foods, sporadic meal skipping, or not having food for a whole day (42). Thus, it is not unexpected to find food insecurity associated with lower SF, as has been reported in U.S. children (43) and adolescents (42). In Inuit preschoolers from 16 communities in Nunavut, no differences were observed in ID or IDA prevalence rates between children from child food-secure and -insecure households, although 99% of the children had consumed TF in the past month (9,10). However, adults appear to moderate their intakes during periods of household food insecurity in order to protect children (11), which may explain this association in adults.

*H. pylori* seropositivity was associated with a lower SF than seronegativity after multivariate adjustment and a reduced risk of elevated iron stores. No relationship was found with risk of low or depleted iron stores. It should be noted that seropositivity was common in the population (73%), limiting the number of the noninfected population for statistical comparisons. In addition, there are limitations with the seropositive test, which reflects any past antigen exposure rather than current infection, leading to misclassification of infection status and attenuation of the association. Nonetheless, our findings support other observations that *H. pylori* infection may contribute to lower SF, but this does not necessarily lead to iron depletion and deficiency (44). Twenty percent of men with depleted iron stores were seronegative, suggesting alternate etiologies.

Iron overload through diet is virtually impossible due to downregulation of nonheme iron absorption as body stores increase (45). Toxicity is related mainly to inappropriate iron supplementation or the genetic defect causing hereditary hemochromatosis, which is most common in males of Northern European descent (45). The prevalence of hemochromatosis among Inuit is unknown and Canadian Inuit may include mixed Inuit and Northern European ancestry. Our logistic model demonstrated a 10-fold increased risk of elevated iron stores for a 10-y increase in age. Adiposity was the only other positive predictor of elevated iron stores. TF use did not affect risk of high iron in our study and use of supplements was rare. Overall prevalence of iron overload was low in our sample and far more common in surveys of Greenlandic Inuit (4,34), possibly due to a greater prevalence of Inuit with mixed Danish and Inuit heritage in Greenland than in our study population, higher TF use and dietary iron intake at the time of the Greenland survey, or a lack of exclusion of participants with inflammation.

There are several important limitations to the study. Blood was collected for one season only (late summer/early fall) and therefore the biochemical assessment of iron status may not accurately reflect dietary intake and TF availability throughout the entire year as examined using the FFQ. Inflammation status was defined by hs-CRP alone and may have underestimated the prevalence of chronic inflammation in the population. Measurement of sTfR on the entire sample or a second and 3rd indicator of iron status would have enhanced the ability to classify participants as ID and IDA. Alcohol intake as assessed (dichotomized into users and nonusers) was not related to iron status in exploratory analyses.

In conclusion, iron depletion does not explain the moderate anemia rate for Inuit men in Canada. Iron stores are largely adequate in this population, although lower than expected based on dietary iron intake. Further research is warranted to understand the regulation of iron metabolism in this population. These data are based on the first representative survey of Inuit men in ISR, Nunavut, and Nunatsiavut. Although previous Inuit surveys have reported IDA and iron overload in Inuit men, these surveys did not account for inflammation or measure functional ID. In terms of modifiable determinants, TF use, TF access, and food insecurity were important correlates of adequate iron stores and TF was the greatest contributor of dietary iron. As traditional lifestyles in the North are increasingly pressured, continued access to micronutrient-rich TF is needed to ensure the health and well-being of Inuit and Northern peoples during this period of transition.

**Acknowledgments**

The authors thank Louise Johnson-Down for dietary analysis, Dr. Brian Ward for *H. pylori* analysis, Sherry Agellon for laboratory training, and Zirong Cao and Dr. Atul Sharma for statistical consultation. J.A.J. was part of the team that conducted the research, analyzed the data, and wrote the manuscript; G.M.E. designed the study, conducted the research, and contributed significantly to data analysis and interpretation; H.A.W. provided consultation for dietary data collection and sample analyses, advice, and data interpretation; and H.V.K. provided consultation for dietary data collection and editorial advice. All authors read and approved the final paper.

**Literature Cited**

2. Canada Bureau of Nutritional Sciences. Reports from Nutrition Canada: the Eskimo Survey report. In: Department of National Health...


770 Jamieson et al.