Vitamin D Status of Inuit Preschoolers Reflects Season and Vitamin D Intake

Jessy El Hayek, Grace Egeland, and Hope Weiler

School of Dietetics and Human Nutrition, McGill University, Montreal H9X 3V9, Quebec, Canada; and Centre for Indigenous Peoples’ Nutrition and Environment, McGill University Macdonald Campus, Sainte-Anne-de-Bellevue, Quebec H9X 3V9m Canada

Abstract

Rickets ascribed to hypovitaminosis D remains a public health concern among Aboriginal children in Canada and the United States. Our primary objective in this study was to investigate the prevalence and risk factors (gender, age, vitamin D intake, and socioeconomic status) for low vitamin D status of Inuit preschoolers living in 16 Arctic communities (51°N-70°N) and participating in the 2007–2008 Nunavut Child Inuit Health Survey. Children were selected randomly in summer (n = 282) and a follow-up was performed in winter for a subsample (n = 52). Dietary intake was assessed through the administration of a 24-h dietary recall and a FFQ. Anthropometric measurements (height, weight) were assessed. Plasma 25-hydroxy vitamin D was measured using a chemiluminescent assay (Liaison, Diasorin). Prevalence of vitamin D insufficiency (<75 nmol/L) among preschoolers was 78.6% and 96.8% in summer and winter, respectively. Median vitamin D concentrations and interquartile ranges in summer and winter were 48.3 (32.8–71.3) and 37.7 (21.4–52.0) nmol/L, respectively. The prevalence of vitamin D deficiency < 25 and < 37.5 nmol/L was 13.6 and 36.5%, respectively. Children who met or exceeded the adequate intake, those who consumed 2 or more milk servings (1 serving = 250 mL), and those who lived in households without crowding (47.7%) had a better vitamin D status than those who did not. The predictors of vitamin D status were dietary intake and age. Given low traditional food consumption and low consumption of milk, interventions promoting vitamin D supplementation may be required. J. Nutr. 140: 1839–1845, 2010.

Introduction

In the United States, national data on rickets prevalence is unavailable; however, a review of reports published between 1986 and 2003 regarding nutritional rickets among children < 18 y of age identified 166 cases in 22 published studies (1). In Canada, a recent pediatric surveillance assessment of rickets estimated 2.9 cases/100,000 infants and children (0–18 y) (2). The majority of cases were characterized by darker skin pigmentation and lack of vitamin D supplementation. The highest incidence rate was observed among children living in the Northwest Territories (15 cases/100,000) and Nunavut (14 cases/100,000). However, only a limited number of studies have assessed vitamin D status of infants and children at high latitudes (2). In addition, evidence suggests that Aboriginal people have low intakes of vitamin D, have shifted toward the consumption of more market foods (3), and have reduced their consumption of traditional foods rich in vitamin D (4). Further, infrequent use of vitamin D supplements (5), darker skin (6), higher obesity rates (7), and northern latitude (2) are risk factors predisposing Arctic Indigenous Peoples to vitamin D deficiency or insufficiency. At northern latitudes, season strongly affects endogenous vitamin D synthesis as a function of solar UVB radiation (290–315 nm) (8). Ineffective synthesis of vitamin D lasts from November through February in Boston (42.2°N); however, at higher latitudes, this period extends to 6 mo. For instance, in Edmonton (52°N) and some parts of Norway (61°N), this ineffective winter period extends from October through March (9).

One of the modifiable risk factors for vitamin D deficiency is dietary intake. It is anticipated that intakes in young children are below current recommendations and are insufficient to meet new status targets (75 nmol/L) set by the Canadian Pediatric Society (CPS) (10). When the 25-hydroxy vitamin D [25(OH)D] concentration exceeds 75 nmol/L, parathyroid hormone (PTH) concentration plateaus in adolescents (11) and intestinal calcium transport increases in 6- to 10-y-old children (12). Although limited data are available on the vitamin D status of Aboriginal youth (13,14), studies conducted in more southern regions in the United States (40°N) and Canada (52°N) (15,16) link low vitamin D intake with lower 25(OH)D concentrations. Furthermore, winter season (14,15), high BMI (17,18), and race (19,20) were important predictors of hypovitaminosis D. The

1 Supported by grants of the International Polar Year and Canadian Institutes for Health Research.
2 Author disclosures: J. Hayek, G. Egeland, and H. Weiler, no conflicts of interest.
* To whom correspondence should be addressed. E-mail: hope.weiler@mcgill.ca.

Abbreviations used: AAP, American Academy of Pediatrics; DV, daily value; CPS, Canadian Pediatric Society; IQR, interquartile range; PTH, parathyroid hormone; 25(OH)D, 25-hydroxy vitamin D.
prevalence of vitamin D insufficiency reported at high latitudes (40°–53°N) in North America ranged from 40 to 93% of children and youth (0–21 y of age) (14–16,21). Also, 25(OH)D concentrations were inversely correlated with PTH among healthy children as an early clinical manifestation of vitamin D deficiency or insufficiency (15,22). All these studies show that youth living at high latitudes in countries where vitamin D fortification is mandatory are at high risk for low vitamin D status. Thus, one would expect that Inuit youth would also be at heightened risk of vitamin D deficiency. Our primary objective in this study was to investigate the prevalence and risk factors (gender, age, vitamin D intake, and socioeconomic status) for vitamin D deficiency of Inuit preschool children living in the Arctic communities (51–70°N).

**Participants and Methods**

**Participants** The sample consisted of Inuit preschool children (3–5 y of age) recruited in the late summer and early fall of 2007 (August–November) and 2008 (August–September) in 16 of the 25 communities of Nunavut, representing all 3 regions of the territory (Kivalliq, Baffin, and Kitikmeot). The communities were selected to be representative of latitude, region, and community size. Latitude of the communities ranged from 56°32′N to 72°40′N. Inclusion criteria for participation consisted of self-identified Inuk by parents or caregiver and 3–5 y of age. Children were recruited from both the community health center lists of age-appropriate children and from randomly selected households with 3- through 5-y olds that had participated in the International Polar Year Inuit Adult Health Survey. A randomized list of children was created from the health center list using a random number table and parents/caregivers were contacted in the order that they appeared on the list. Caregivers were contacted either by phone, when available, or in person. Of the 353 successfully contacted households, 75 refused upon initial contact and 74 cancelled or failed to attend the study appointment; thus, the overall participation rate was 72.3% and 388 children were recruited. A more detailed description of the population characteristics and survey methodology is available elsewhere (23,24).

**Ethics** The study was approved by the McGill Faculty of Medicine Institutional Review Board and by the Nunavut Research Institute. A parent or primary caregiver provided signed informed consent. A person was considered a child’s primary caregiver if he/she was the person primarily responsible for the child at the time of the study. Consent forms and an information DVD were available in English and Inuit languages.

**Research team and interviews** The research team consisted of bilingual interviewers who conducted face-to-face interviews. Information about household composition, living conditions, diet, supplement use, and health status were collected through interviews with the child’s caregiver. Statistics Canada’s definition of more than 1 person per room where rooms included bedrooms, kitchen, and living room was used to define household crowding.

A qualitative FFQ (without assessment of portion sizes) was completed by the child’s caregiver. The FFQ reflected the previous month and contained 30 commonly consumed traditional food items, some of which are considered good sources of vitamin D (whitefish, arctic char, seal meat, seal liver, caribou, caribou liver, polar bear meat, walrus meat, whale meat, land birds, duck, and goose). It also contained the following market food sources of vitamin D: milk, margarine, and eggs. Furthermore, 24-h dietary recalls were conducted with the caregiver using a multiple pass technique. Portion sizes were estimated using a 3-dimensional food model kit (Santé Quebec) to better standardize 24-h dietary recalls. Interviewers recorded if there were times when the caregiver did not know what the child ate. Daycares were called regarding daycare snacks and meals to complete dietary recall. This approach has been shown to be an accurate method of assessing intake in this age group (25). Twenty-percent of the caregivers were asked to return for a repeat 24-h dietary recall, which was conducted on a nonconsecutive day. Thus, vitamin D intake was adjusted for the second 24-h recall and an estimation of the adjusted vitamin D intake was calculated following the guidelines by the Institute of Medicine (26). The Iowa State Software for Intake Distribution Estimate (Iowa State University, 1996) was used to adjust vitamin D and milk intake including adjustments for sequence and day of the week. The adjusted data were used to compare intakes against the adequate intake and recommended servings of milk for preschool children (1 serving = 250 mL).

Because the FFQ did not include portion size, we derived from the 24-h recall the median portion size of milk consumed at 1 sitting and we multiplied it by the frequency of consumption (from the FFQ) to have a more quantitative assessment of milk intake. Sources of vitamin D were defined as ≥5% of daily value (DV), a good source was defined as ≥10% of DV, and an excellent source was defined as ≥20% of DV (27). Vitamin or mineral supplement use and frequency were recorded.

**Clinical assessments** Venous blood (3 mL) was collected into heparin-coated vacutainers followed by centrifugation and storage of plasma at −20°C and was then transported on ice packs to McGill University and stored at −80°C until analysis. Blood was drawn from children in summer (n = 282) and a follow-up was performed in winter (February–April) for a subsample (n = 52). Height was measured to the nearest 0.1 cm using a portable stadiometer (Road Rod214 Portable Stadiometer, Seca) and weight was measured to the nearest 0.1 kg using an electronic scale. BMI and weight-for-age were calculated and interpreted using the WHO Child Growth Charts for children (28).

**Laboratory analysis** Plasma 25(OH)D and PTH concentrations were measured using LIASON total 25(OH)D and PTH assays (DiaSorin) at McGill University. The inter-assay and the intra-assay CV% were 4.5 and 11.1% for the low 25(OH)D control (38.2 nmol/L) and 6.2 and 5.3% for the high 25(OH)D control (127.2 nmol/L); the accuracy using the mid range of the manufacturer’s specifications was 95%. For the PTH low control, the inter-assay CV% was 19.1 (49.8 ng/L) and 8.7 for the high PTH control (494 ng/L). The accuracy using the mid range of manufacture specifications was 86.7%. The laboratory that measured 25(OH)D participated in the Vitamin D External Quality Assessment Scheme program and obtained a certificate of proficiency for 2009–2010, which reflects that ≥80% of the reported results fell within 30% of the All-Laboratory Trimmed Mean.

The best indicator of vitamin D status is 25(OH)D concentration (29), as it reflects both exogenous and endogenous vitamin D intake. Two definitions for vitamin D deficiency have been suggested: 25(OH)D concentrations either <25 nmol/L or <37.5 nmol/L. The former concentration correlates clinically with rickets and osteomalacia (14,30) and the latter correlates with increased bone loss as a consequence of secondary hyperparathyroidism (31–33). For optimal bone health, 25(OH)D concentrations >75 nmol/L have been recommended given that PTH concentrations attain a plateau and intestinal calcium transport increase (10,14). Because there is no consensus on the definition of vitamin D deficiency in pediatric populations, results are presented using multiple definitions to allow for comparison with other studies. The American Academy of Pediatrics (AAP) defines vitamin D status on the basis of 25(OH)D: deficient (<37.5 nmol/L), insufficient (<50 nmol/L), and sufficient (≥50 nmol/L) (34), whereas the CPS defines vitamin D on the basis of 25(OH)D: deficient (<25 nmol/L), insufficient (<75 nmol/L), and optimal (≥75 nmol/L) (10).

**Statistical analysis** Questionnaires and clinical information were entered into a Microsoft Access Database and 24-h dietary recall data were entered using CANDAT (Godin London). Prevalence of vitamin D deficiency and insufficiency was estimated as the proportion of participating children presenting with the condition. Weighted prevalence estimates were calculated using the number of all age-eligible Inuit children obtained from health center lists. Plasma 25(OH)D concentrations showed skewed distribution, so a log transformation was performed prior to statistical analyses. ANOVA was used to determine whether plasma the 25(OH)D concentration was different based on intake of milk using unadjusted data from 24-h recall and FFQ plus household crowding followed by Bonferroni’s post hoc tests when-
Results

Although 388 children participated in the health survey, not all caregivers consented to the collection of a venous blood sample on their child. Children with available 25(OH)D concentrations \(n = 282\) were similar to those with unavailable values \(n = 106\) for age, gender, BMI percentile, demographics, the number of hours spent outside, adequate intake for vitamin D from all sources, and amount of traditional foods consumed the previous day. Thus, results are presented for only the 282 children with available 25(OH)D concentrations.

The sample consisted of 132 boys and 150 girls (Table 1). History of health conditions included 6 cases of rickets. The weighted prevalence of taking multivitamins was 16.8% (95% CI: 11.9–22.6) \((n = 276)\). Calcium intake was relatively high among Inuit children. The major source of calcium was milk for drinking contributing to 27.9% of total calcium intake. Dairy products, including total milk, yogurt, cheeses and soups, contributed to 47.6% of total calcium intake.

The IQR of plasma 25(OH)D concentrations during the summer season (August–November) was [32.8–71.3 nmol/L], with a median of 48.3 nmol/L (Table 2) and the IQR of plasma 25(OH)D concentrations \(n = 52\) during the winter season (February–April) was [21.5–52.0 nmol/L], with a median of 37.8 nmol/L. The median summer 25(OH)D concentrations were higher than winter 25(OH)D concentrations \((P < 0.01)\), with a mean difference of 16.3 ± 24.1 nmol/L. Using the CPS definition, the weighted prevalence of 25(OH)D insufficiency (<75 nmol/L) among preschool Inuit children was 78.6% in summer and 96.8% in winter. Using the AAP definition, the weighted prevalence of 25(OH)D insufficiency (<50 nmol/L) among preschool Inuit children was 51.7% in summer and 72.8% in winter. Furthermore, summer and winter 25(OH)D concentrations were positively correlated \((r = 0.6; P < 0.01)\). Using a multiple linear regression model, including gender, milk intake (yes/no), length of time between summer and winter measurements, and summer 25(OH)D concentrations to predict winter 25(OH)D concentrations, only summer 25(OH)D concentrations were predictors of winter concentrations \((\beta = 0.3; SE = 0.09, intercept = 29.0; P \leq 0.01)\). Plasma PTH and 25(OH)D concentrations were not correlated \((r = 0.0; P = 0.5)\). Vitamin D status of the winter subsample in both summer and in winter is presented in Figure 1.

The adjusted 24-h recall vitamin D intake was 6.3 ± 2.9 \(\mu\)g \((n = 275)\) and 61.4% of the children met or exceeded the AI (5 \(\mu\)g). Children who met or exceeded the AI for vitamin D had a better vitamin D status compared with those who did not meet the AI \((P < 0.01)\). The major contributor to total vitamin D intake in preschoolers was market food (84.1%) compared with traditional foods (15.9%), because 53.7% of the children did not consume any traditional foods in the previous day and there was a low intake of traditional foods rich in vitamin D.

Using the FFQ, the median frequency of consumption of arctic char, whitefish, or beluga oil during the past month was <2/mo (Table 3). In addition, the mean intake of fish was 3.8 ± 6.8 times/mo and 33.6% of children did not consume fish at all in the previous month. However, the median frequency of

---

**TABLE 1** Selected characteristics of children with available plasma 25(OH)D concentrations (Nunavut Inuit Child Health Survey, 2007–2008)\(^1\)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>(n)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys, %</td>
<td>132</td>
<td>46.8</td>
</tr>
<tr>
<td>Vitamin D supplements, % yes</td>
<td>279</td>
<td>3.7</td>
</tr>
<tr>
<td>Age, y</td>
<td>282</td>
<td>4.4 ± 0.9</td>
</tr>
<tr>
<td>BMI, kg/m(^2)</td>
<td>280</td>
<td>18.4 ± 2.2</td>
</tr>
<tr>
<td>BMI percentile(^2)</td>
<td>280</td>
<td>90.1 ± 15.1</td>
</tr>
<tr>
<td>Adjusted vitamin D intake, (^3) (\mu)g/d</td>
<td>275</td>
<td>6.3 ± 2.9</td>
</tr>
<tr>
<td>Adjusted calcium intake, (^3) mg/d</td>
<td>275</td>
<td>922.7 ± 344.1</td>
</tr>
</tbody>
</table>

\(^1\) Values are median [IQR] or percent (95% CI).
\(^2\) According to WHO (28).
\(^3\) Adjusted for repeat recall according to the Institute of Medicine (26).

---

**TABLE 2** Weighted prevalence of vitamin D deficiency, insufficiency, and sufficiency assessed by plasma 25(OH)D concentrations in Inuit preschoolers in summer and winter by CPS and AAP targets (Nunavut Inuit Child Health Survey, 2007–2008)\(^1\)

<table>
<thead>
<tr>
<th>Plasma 25(OH)D, nmol/L</th>
<th>CPS(^2)</th>
<th>AAP(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deficient, &lt;25</td>
<td>Insufficient, 25 to &lt;75</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25(OH)D, nmol/L ((n = 282))</td>
<td>19.1 [17.1–22.7]</td>
<td>45.8 [34.7–58.5]</td>
</tr>
<tr>
<td>Weighted prevalence, %</td>
<td>13.9 [9.6–18.3]</td>
<td>64.9 [58.8–70.9]</td>
</tr>
<tr>
<td>Winter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25(OH)D, nmol/L ((n = 52))</td>
<td>17.9 [16.2–20.8]</td>
<td>42.2 [38.9–52.9]</td>
</tr>
<tr>
<td>Weighted prevalence, %</td>
<td>34.1 [19.4–48.9]</td>
<td>62.8 [47.7–77.5]</td>
</tr>
</tbody>
</table>

\(^1\) Values are median (IQR) or percent (95% CI).
\(^2\) (10).
\(^3\) (34).
consumption of milk and eggs was more common than traditional foods. Using the 24-h recall, milk contributed to 34.5% (2.3 μg) of the overall vitamin D intake of the children. The median intake of milk of Inuit preschool children was 140.7 (0–375.7) mL/d, which reflects 0.6 (0–1.5) servings of milk. Only 32.5% of the children consumed the number of milk servings recommended by the Canadian food guide (2 servings) for First Nations, Inuit, and Metis (Fig. 2). Children who did not consume milk at all and those who consumed <2 servings of milk had significantly lower vitamin D status than those who consumed ≥2 servings of milk. These results were confirmed when the data of both the 24-h dietary recall (median portion size of milk at 1 sitting) and FFQ (daily frequency consumption of milk) were combined (Table 4). On the other hand, plasma 25(OH)D concentrations were similar in children who did and those who did not consume traditional food sources of vitamin D. Also, children who lived in crowded households had a lower vitamin D status compared with those who lived in households with no crowding (P = 0.02) (Table 3).

Median plasma 25(OH)D concentrations did not differ by age, gender, BMI, latitude, type of housing, or the presence of an active hunter in the household.

Finally, daily vitamin D intakes ≥ 5 μg (AI) and age were significant predictors of an optimal vitamin D status defined as >75 nmol/L and only intakes at or above AI remained a significant predictor when optimal vitamin D status was defined as >50 nmol/L (Table 5).

## Discussion

In this representative sample of Inuit children, even at the end of summer, when plasma 25(OH)D concentrations should be at their highest, 78.6% of children had low vitamin D status using the CPS definition while 51.7% of the children were insufficient using the AAP definition. In winter, 96.8% of a subsample of the children had low vitamin D status using the CPS definition while 72.8% of the children were insufficient using the AAP definition. Irrespective of the definition used, these results revealed a relatively high prevalence of 25(OH)D deficiency and insufficiency, particularly in winter. In contrast, the prevalence of vitamin D insufficiency (<75 nmol/L), over the entire year, was lower (51.4%) among children (6–11 y) from the Canadian Health Measures Survey, which excluded residents of Indian reserves, crown lands, and certain remote regions (35). However, findings from the present study are in agreement with targeted studies of Canadian Aboriginal children at high

### TABLE 3  
Vitamin D concentrations and frequency of consumption of selected vitamin D-containing food sources by Inuit preschoolers (Nunavut Inuit Child Health Survey, 2007–2008)

<table>
<thead>
<tr>
<th>Food</th>
<th>Vitamin D, μg/100 g</th>
<th>Frequency of consumption, n/mo</th>
<th>Children, n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>1.0–1.1</td>
<td>30.4 (0–212.8)</td>
<td>241</td>
</tr>
<tr>
<td>Eggs</td>
<td>1.3</td>
<td>8.7 (0–60.8)</td>
<td>241</td>
</tr>
<tr>
<td>Margarine</td>
<td>13.3</td>
<td>2.0 (0–80.8)</td>
<td>142</td>
</tr>
<tr>
<td>Arctic char</td>
<td>0.5–3.7</td>
<td>2.0 (0–43.4)</td>
<td>178</td>
</tr>
<tr>
<td>Whitefish</td>
<td>15.0</td>
<td>0 (0–8.7)</td>
<td>12</td>
</tr>
<tr>
<td>Beluga oil</td>
<td>26</td>
<td>0 (0–10.0)</td>
<td>9</td>
</tr>
</tbody>
</table>

1 According to the Canadian Nutrient File (53).
2 Values are medians (range) for the previous month intake.
3 FFQ data were available for 277 children.

### FIGURE 1  
Vitamin D status of Inuit preschool children in the winter subsample (n = 52) in the summer (August–November) and winter (February–April) seasons according to the CPS (10) and AAP (34) targets (Nunavut Inuit Child Health Survey, 2007–2008).

latitudes (13). Similarly, Newhook et al. (14) reported that 77% of children, 0–14 y old and living in St John (47°N), Newfoundland, who presented to the hospital (n = 65) had 25 (OH)D concentrations < 75 nmol/L (winter and summer season combined). At a higher latitude (52°N), among participants 2–16 y old who presented to the pediatric emergency (n = 90) in Edmonton, Alberta, 34% had vitamin D insufficiency (<40 nmol/L) and 6% were deficient (<25 nmol/L) at the end of winter (16). Furthermore, the study findings concur with studies among youth at high latitudes in the United States (40–42°N) (15), New Zealand (36) (35–46°S), and the United Kingdom (53°N) (37).

The inverse relationship between plasma 25(OH)D and PTH was not observed in the present study. This relationship was observed in several studies (15,22). It has been observed that dietary calcium absorption appeared to be more efficient in Inuit children (38); furthermore, calcium intake of Inuit preschool children (923 mg) was above AI (800 mg), which may explain the lack of relationship between PTH and 25(OH)D concentrations. All but 7 children had normal PTH concentrations (14–66 ng/L) (39).

Children who lived in crowded households compared with those who did not had lower vitamin D concentrations. Household crowding has been previously associated with poor health conditions (40). Inuit children were ~6 times more likely to live in crowded households compared with their non-Aboriginal counterparts (41). Crowding may be related to food security, an emerging concern among many populations.

Vitamin D adjusted daily intake of Inuit preschool children (6.3 μg) was similar to other Canadian children, 2–16 y old, in Alberta (6.3 μg) (16); however, it was higher than in 9- to 12-y-old Cree children (n = 201) who had a vitamin D intake of 3.9 μg/d (from three 24-h recalls) (42). It might be possible that the lower vitamin D intake in the Cree children may be underestimated depending on the database used and whether missing values of vitamin D in the Canadian Nutrient File were taken into consideration. It has been reported that even though Inuit are experiencing the nutrition transition and are consuming more market foods (43), they are still consuming a higher percentage of their daily energy intake from traditional foods compared with other Aboriginal People in Canada (5). Recently, we published nutrient intakes of Inuit preschoolers using all available 24-h recall data (n = 374) (39). Dietary vitamin D...
intake was higher with higher consumption of traditional foods and therefore the percent above the AI for vitamin D was 43.1, 56.8, and 83.2% among nonconsumers of traditional foods, low consumers (<183 g/d), and high consumers of traditional foods (>183 g/d) (44). However, in the present analysis (n = 275) using the FFQ, children who consumed excellent and good traditional sources of vitamin D did not have a better vitamin D status, most likely ascribed to the low or occasional consumption of those foods (<1 serving/d). In Nuuk, Greenland (64°N), Rejnmark et al. (45) reported that vitamin D insufficiency [plasma 25(OH)D < 50 nmol/L] was more prominent among Inuit adults aged 22–61 y following a Western diet during the winter season (81%) than those following a traditional diet (42%). Upon examination of the 24-h recall, besides milk, no one food contributed to the total vitamin D intake by >6%. For instance, the contributions of Arctic char and caribou were 5.5 and 3.7%, respectively, and the contributions of eggs and margarine were 2.9 and 2.5%, respectively. The major contributor to total vitamin D intake was milk. The contribution of milk to the total vitamin D intake in Inuit preschool children (34.5%) was lower than that observed among Canadian children 1–18 y of age in the Canadian Community Health Survey 2004 (45–65%) (46). However, more Inuit children (32.5%) consumed the 2 milk servings recommended by the Canadian Food Guide compared with Cree children (19.1%) (42). Also, children who did not consume milk at all and those who consumed <2 servings of milk had significantly lower vitamin D status than those who consumed ≥2 servings of milk. Regardless of assessment using the FFQ or 24-h dietary data, the interpretation was the same. These findings suggest that sun exposure is not masking the effect of dietary intake from traditional foods. Thus, if Inuit preschool children improve consumption of traditional foods rich in vitamin D and milk, vitamin D status is anticipated to improve.

A better vitamin D status was associated with meeting or exceeding the AI (P < 0.01). Inuit preschool children who met or exceeded the AI were 1.8–2.6 times more likely, depending on the definition of optimal status, to have a better vitamin D status than children who did not meet the AI. Similarly, other studies (15,16) have identified vitamin D intake as a predictor of vitamin D status. Also, younger children had a 34% lower risk of having a suboptimal vitamin D status when optimal vitamin D status was defined as 25(OH)D < 75 nmol/L. On the other hand, age was not a significant predictor of vitamin D status when optimal vitamin D status was defined as 25(OH)D < 50 nmol/L. However, age was reported earlier as a predictor of vitamin D status among youth (2–21 y old) in both Canada and the United States (15,16). The age-related differences in vitamin D status could not be attributed to a lower vitamin D intake nor a higher BMI, because we did not see any difference in the vitamin D intake or BMI percentile of different age groups. The use of BMI to assess adiposity in children and adolescents has been found to have limited value (47) and data about physical activity, overall body fat, and lean body mass were not assessed in the present study. It would have been of interest to assess these variables, because adiposity negatively correlates with vitamin D status (48,49) and lean body mass and physical activity positively correlate with vitamin D status (50). However, the magnitude of reduction in vitamin D status due to obesity is minimal and cannot fully explain the low 25(OH)D observed.

The major strength to this study is that, to our knowledge, it is the first comprehensive study to simultaneously assess the vitamin D status of Inuit preschoolers in combination with vitamin D intake, age, gender, latitude, BMI, and other known predictors of vitamin D status. However, the study findings cannot be generalizable beyond Inuit preschoolers and because the study was cross-sectional in nature, causality cannot be inferred. Further, there is a controversy whether immunoassays underestimate plasma 25(OH)D (51); however, 25(OH)D targets were based primarily on immunoassays (52) and the associated functional outcomes (11,12). Therefore, the 50% vitamin D insufficiency is not likely ascribed to assay discrepancies.

In conclusion, 25(OH)D deficiency and insufficiency were highly prevalent in Inuit preschoolers living in Nunavut even at the end of summer, when 25(OH)D concentrations should be at their highest and traditional foods should be abundant. Given low traditional food consumption and low consumption of milk, interventions promoting vitamin D supplementation may be required to achieve 25(OH)D concentrations of 75 nmol/L.
Further vitamin D status assessments, particularly in the winter, across wider age ranges in the Arctic are encouraged. Other Aboriginal children might be at high risk of vitamin D deficiency due to low consumption of traditional foods and thus other population studies are warranted to establish prevalence of vitamin D deficiency are advised.

Acknowledgments
We thank Zhirong Cao for her contribution to the data management and statistical advice, Louise Johnson-Down for her assistance in the analysis of the dietary data, and Sherry Agellon for her help with the measurements of 25(OH)D and PTH concentrations. G.E. and H.W. designed research; J.H., G.E., and H.W. conducted research; G.E. and H.W. provided essential materials and reagents; J.H. analyzed data; J.H. wrote the manuscript and G.E. and H.W. critically reviewed the manuscript; and J.H. had primary responsibility for final content. All authors read and approved the final manuscript.

Literature Cited

### TABLE 5 Characteristics predicting of plasma 25(OH)D concentrations in multivariable logistic regression analyses (Nunavut Inuit Child Health Survey, 2007–2008)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio [95% CI]</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal status, &gt; 75 nmol/L$^1$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted intake of vitamin D $= \text{AI} \geq 5 \text{ug/d vs.} &lt;5 \text{ug/d}$</td>
<td>2.2 [1.1–4.3]</td>
<td>0.02</td>
</tr>
<tr>
<td>Age, y</td>
<td>0.7 [0.5–1.0]</td>
<td>0.03</td>
</tr>
<tr>
<td>BMI, kg/m$^2$</td>
<td>0.9 [0.8–1.1]</td>
<td>0.51</td>
</tr>
<tr>
<td>Gender, girls vs. boys</td>
<td>1.7 [0.9–3.1]</td>
<td>0.10</td>
</tr>
<tr>
<td>Sufficient status, &gt; 50 nmol/L$^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted intake of vitamin D $= \text{AI} \geq 5 \text{ug/d vs.} &lt;5 \text{ug/d}$</td>
<td>2.6 [1.6–4.4]</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Age, y</td>
<td>0.8 [0.6–1.1]</td>
<td>0.20</td>
</tr>
<tr>
<td>BMI, kg/m$^2$</td>
<td>0.9 [0.8–1.1]</td>
<td>0.40</td>
</tr>
<tr>
<td>Gender, girls vs. boys</td>
<td>1.0 [0.6–1.6]</td>
<td>0.96</td>
</tr>
</tbody>
</table>

$^1$ Latitude did not contribute to the model.

$^2$ Adjusted for age, BMI, and gender.


