

Vitamin D Intake From Food and Supplements Among Ontario Women Based on the US Block Food Frequency Questionnaire With and Without Modification for Canadian Food Values

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ABSTRACT

Objectives: To measure and compare dietary vitamin D intake among women in Ontario using a modified Block 1998 (US) food frequency questionnaire (FFQ) before and after modification for Canadian-specific vitamin D food fortification.

Methods: An age-stratified random sample of 3,471 women in Ontario (aged 25-74) was identified using random digit dialing methods. Standard US food values and a modified Canadian-specific vitamin D nutrient analysis were applied to the FFQ.

Results: Intake of vitamin D from foods (Canadian nutrient analysis) was 5.3 ± 3.4 µg/day (mean \pm SD) and 45% of women reported vitamin D intake from supplements. Total vitamin D intakes met the current Adequate Intakes of 5, 10 and 15 µg/day for only 62%, 47%, and 28% of women aged ≤ 50 , 51-70 and ≥ 71 , respectively. Relatively high agreement was found between the US and Canadian nutrient analysis methods of measuring vitamin D from food (weighted kappa = 0.74, 95% CI 0.72-0.76). Intake differences (US minus Canadian) ranged from -5.0 µg/day to +2.0 µg/day (1st-99th percentile); however, the mean difference was only -0.54 µg/day (95% CI: -0.58 to -0.50).

Conclusions: Lower than recommended total vitamin D intakes were observed among our study participants which may negatively impact the health status of women. Adjustment for Canadian food fortification and the inclusion of fatty fish had little impact on the measurement of vitamin D from food.

Key words: Vitamin D; food, fortified; nutrition surveys; female; Canada; United States

La traduction du résumé se trouve à la fin de l'article.

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Vitamin D is important for maintenance of healthy bones, and low vitamin D intake may be a risk factor for some cancers and other chronic diseases.¹⁻³ Vitamin D is synthesized by the skin following sunlight exposure and is present in foods and supplements. Since few foods contain high amounts of vitamin D,⁴ many countries have their own food fortification policies to improve vitamin D levels. In Canada, fortification of fluid milk and margarine with vitamin D is mandatory.⁵ Manufacturers are permitted to use fortified milk to make milk products (e.g., yoghurt) and to fortify milk beverage substitutes, and some other foods such as orange juice, but these items are not universally enriched. In the United States (US), where vitamin D fortification is optional, most milk and many breakfast cereals are fortified.⁶

In Canada and the US, vitamin D intakes are evaluated against Adequate Intakes (AIs). The AIs for vitamin D are 5, 10 and 15 µg/day for adults ≤ 50 , 51-70 and ≥ 71 years of age, respectively.⁷ Measuring diet is important for nutritional epidemiology studies and surveillance and a commonly used tool is the food frequency questionnaire (FFQ). American FFQs are frequently applied in such studies, without modifying nutrient databases for population-specific food values. Few studies⁸ have investigated the impact of this practice on the measurement of vitamin D intakes.

The objectives of the current study were to 1) describe vitamin D intake from food and supplements among women in Ontario, and 2) compare vitamin D intakes using a US nutrient analysis versus a

modified analysis that reflects additional vitamin D sources (fatty fish) and Canadian food fortification.

METHODS

Study description

Women aged 25-74 years were identified using random digit dialing of households in Ontario between 2002 and 2003. These women were recruited as controls for a case-control study evaluating various epidemiologic factors and breast cancer risk.⁹ This study was approved by the University of Toronto Research Ethics Board. Of 4,352 households with eligible women, 3,471 (80%) completed a mailed self-administered risk factor questionnaire and an FFQ.

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Conflict of Interest: TB is an owner of NutritionQuest, which holds the copyright on the Block FFQ. LNA, MC, BAB and JAK have none to declare.

Table 1. Vitamin D Food Values Assigned to the Standard (US) Nutrient Analysis and the Modified Canadian Analysis

Foods	Vitamin D Values	
	US*	Canada†
	µg per 100g	
Breakfast cereals	3.5	0
Margarine	1.5	13.3
Fish (not fried)‡	1.5	–
Fatty fish	–	10.0
White fish	–	1.5
Milk	1.0	1.0

* Values from Block Dietary Data Systems.

† Values from Canadian Nutrient File.

‡ Fish type was added to the modified Canadian analysis and a higher value was assigned to fatty fish. The type of fish question was not applied to the US analysis.

Subjects were asked about foods and supplements they “usually ate about two years ago”.

Measurement of vitamin D (FFQ and database values for nutrient analysis)

Description of the FFQ

The quantitative Block 1998 FFQ⁹ used in this study was modified to improve measurement of specific dietary components, including vitamin D, and included 178 food items. A subquestion querying the type of fish eaten most often (white or fatty), and a supplement item for vitamin D or cod-liver oil were added to the FFQ. Validity was assessed against two 24-hour recalls among Ontario women using US nutrient data.¹⁰ Based on usual (current) intake, FFQ reliability for vitamin D was relatively high (non-deattenuated $r = 0.76$, 95% CI 0.66-0.83), and its validity was moderately high (deattenuated $r = 0.54$, 95% CI 0.29-0.79).¹⁰

Description of the Standard (US) and Modified (Canadian) Nutrient Analyses

Vitamin D intake from food was initially measured by applying standard US nutrient values from Block Dietary Data Systems (BDDS) to the FFQ. Nutrient values were based on the US Department of Agriculture (USDA) National Nutrient Database,¹¹ and published literature. BDDS uses national US consumption data to estimate and weight the proportionate use of foods within each FFQ item.^{12,13}

To modify the nutrient analysis for Canada, vitamin D values of all relevant foods in the BDDS FFQ database were compared to corresponding foods in the Canadian Nutrient File (CNF), Canada's standard reference database.⁴ Table 1 presents vitamin D values assigned to the primary food sources on the FFQ. The added fish question, only incorporated in the Canadian analysis, assigned a higher vitamin D value to women reporting they most often consumed fatty rather than white fish based on average fish values in the CNF. Items with very low levels of naturally occurring vitamin D were not modified despite some observed differences between the BDDS (US) nutrient values and those listed in the CNF. BDDS' standard US-based consumption weighting values were used in both analyses.

Supplement Analysis

The analysis for vitamin D from supplements (multivitamins, and vitamin D supplements or cod-liver oil) was not modified as there are no data suggesting a consistent difference in the vitamin D con-

Table 2. Distribution of Subject Characteristics among All Participating Ontario Women (n=3393)

Variable	n (%)*
Age (years)	
25-50	1251 (37)
51-70	1902 (56)
71-74	240 (7)
Highest level of education	
Elementary or High school	1716 (51)
Postsecondary	1664 (49)
BMI† (kg/m ²)	
<24.9	1506 (45)
25.0-29.9	1145 (34)
≥30	719 (21)
Smoking status	
Never-smoker	1741 (51)
Former smoker	1107 (33)
Current smoker	523 (15)
Ethnicity	
Caucasian	3062 (91)
South East Asian‡	95 (3)
Black	50 (2)
Other	169 (5)

* Numbers may not add to totals because of missing values and/or rounding.

† BMI calculated as weight two years ago in kilograms divided by height in metres squared.

‡ e.g., Japanese, Chinese, Korean, Vietnamese.

tent of supplements between Canada and the US. BDDS assigned a vitamin D value of 10 µg to multivitamins; 10 µg was also assigned to the additional vitamin D supplement or cod-liver oil question.¹⁴

Statistical analysis

The frequency distributions of respondent characteristics and vitamin D intake were tabulated. Four vitamin D intake variables are reported: 1) Canadian vitamin D from foods (values from the CNF); 2) US vitamin D from foods (US values provided by BDDS); 3) vitamin D from supplements; and 4) total vitamin D (combined vitamin D from supplements and Canadian food values). The weighted kappa statistic and 95% CI were calculated to assess the chance-corrected agreement between categories of vitamin D intakes obtained from the Canadian and US food analyses. The paired t-test was used to determine if the mean difference between the Canadian and US analyses using the continuous measures of vitamin D from foods was different from zero. Statistical analysis was conducted using SAS version 9.1.

RESULTS

Data analysis was completed on 3,393 of the 3,471 (98%) questionnaires; 44 were considered incomplete due to a large number of missing responses and 34 were excluded due to unlikely energy intakes (<500 or >4500 kcal per day). The maximum daily vitamin D intakes from food and supplements were 30 µg and 20 µg, respectively, and seemed plausible. Table 2 describes the distribution of subject characteristics.

Using Canadian values, the proportion of women meeting the AI for vitamin D from food alone decreased with age (Table 3); 44% of women age 25-50 met the AI of 5 µg/day, only 10% of women age 51-70 met the AI of 10 µg/day, and no women age 71-74 met the AI of 15 µg/day. Most women (55%) did not consume any vitamin D from supplements (single product vitamin D/cod-liver oil, or multivitamin); 38% were multivitamin users and 14% were vitamin D/cod-liver oil users (7% took both). For total vitamin D intake (supplements and Canadian food values), only 62% of women age 25-50, 48% of women age 51-70, and 28% of women age 71-74 had

Table 3. Distribution of Vitamin D Intake among Ontario Women (Total and Stratified by Age Group)

Vitamin D Intake (µg/day)	Total (n=3393) n (%)	Age Group (Years)		
		25-50 (n=1251) n (%)	51-70 (n=1902) n (%)	71-74 (n=240) n (%)
Foods – Cdn values				
<5	1877 (55)	699 (56)	1043 (55)	135 (56)
5-9.9	1193 (35)	435 (35)	670 (35)	88 (37)
10-14.9	280 (8)	102 (8)	162 (8)	16 (7)
≥15	43 (1)	15 (1)	27 (2)	1 (0)
Foods – US values				
<5	2096 (62)	751 (60)	1195 (63)	150 (63)
5-9.9	1049 (31)	394 (31)	573 (30)	82 (34)
10-14.9	223 (7)	94 (8)	121 (6)	8 (3)
≥15	25 (1)	12 (1)	13 (1)	0 (0)
Supplements*				
0	1875 (55)	787 (63)	973 (51)	115 (48)
1-4.9	230 (7)	113 (9)	104 (5)	13 (6)
5-9.9	178 (5)	74 (6)	99 (5)	5 (2)
10-14.9	940 (28)	246 (20)	606 (32)	88 (37)
≥15	170 (5)	31 (2)	120 (6)	19 (8)
Total†				
<5	1132 (33)	475 (38)‡	583 (31)‡	74 (31)‡
5-9.9	825 (24)	363 (29)	413 (22)‡	49 (20)‡
10-14.9	729 (21)	229 (18)	449 (24)	51 (21)‡
≥15	707 (21)	184 (15)	457 (24)	66 (28)

* Supplemental vitamin D includes multivitamins and vitamin D supplements or cod-liver oil.

† Total vitamin D from food (Canadian nutrient values) and supplements.

‡ Intakes below the AI for that age group; daily AI for age 25-50 = 5 µg, age 51-70 = 10 µg, and age ≥71 = 15 µg.

total vitamin D intake that met the AI for their age range. No women had total dietary vitamin D intakes greater than the tolerable upper intake level (50 µg/day).

Mean (± SD) vitamin D intake from supplements alone was 4.4 ± 5.7 µg/day and total combined intake was 9.7 ± 6.9 µg/day. Mean (± SD) intake of vitamin D from food was 5.3 ± 3.4 and 4.8 ± 3.2 µg/day for the Canadian and US nutrient analyses, respectively. The mean US minus Canadian food difference was -0.54 µg/day (95% CI: -0.50 to -0.58) (p<0.0001) and the distribution of differences (1st - 99th percentile) ranged from -5.0 µg/day to 2.0 µg/day. There was relatively high agreement between the categories of vitamin D intake from food alone, using US and Canadian values (weighted kappa = 0.74, 95% CI: 0.72-0.76). However, an additional 4%, 3% and 0% of women age 25-50, 51-70 and 70-74, respectively, would be misclassified as having 'inadequate' intake from food if US values were relied upon (Table 3).

DISCUSSION

Even after modification for Canadian-specific values, low intake of total combined vitamin D (foods and supplements) was observed in our study and was most pronounced among women age 71-74, despite their higher use of supplements. High agreement and limited misclassification were observed between the two food measures, suggesting the standard US Block FFQ and nutrient analysis may be adequate for the measurement of vitamin D foods among Canadians. Using a standard FFQ with US food values can both over- and underestimate Canadian vitamin D intakes, although the magnitude of the mean difference was relatively small.

One previous study examined differences in US versus Canadian vitamin intakes using an FFQ and also found mean Canadian vitamin D intake was slightly underestimated using US values.⁸ This study, conducted in Alberta among 7,659 women age 35-69, also reported few women meeting the AI for vitamin D from food only (30% of women age 31-50, and only 3% of women age 51-70); supplement intake was not described.⁸ The Canadian Community Health Survey (CCHS), a population-based survey of food only

using 24-hour recalls (Canadian nutrient analysis), suggests the AI are met by only 36%, 42% and 9.3% of Canadian women ages 19-30, 31-50, and 51-70, respectively (supplement data are not currently available).¹⁵ The CCHS¹⁵ reports higher intakes of vitamin D from food than measured by FFQ in our study or Csizmadia et al.⁸ but still suggests a large proportion of women are not meeting the current AIs. The inclusion of supplements in our study increased the proportion of women meeting the AIs but the results still indicate that many women may have inadequate intakes of vitamin D. Since our data were collected in 2002-2003 reflecting 2000-2001 intake, it is possible that recent mass media describing the potential benefits of vitamin D may have led to increased vitamin D intake from food and/or supplements.

A potential limitation of any dietary study is measurement error. There are concerns regarding the accuracy of the analysis of vitamin D content of foods^{16,17} and the amount (as reported in nutrient databases) has been found to vary greatly in both fish¹⁸ and fortified milk.^{19,20} FFQs are also a source of measurement error in nutritional epidemiology and are best used to capture relative rather than absolute individual intake.^{21,22} However, the measurement of usual vitamin D using this FFQ was shown to have moderately high validity and mean intake was not significantly different when compared to two 24-hour recalls.¹⁰ Although our study measured usual diet 'two years ago', diet is expected to be stable over time.²³ An additional limitation is that nutrient databases change over time and we applied the most recent version of the CNF to earlier intake data. The lack of modification of nutrient databases for country-specific vitamin D fortification regulations likely introduces error that may bias disease association study findings, although we found high agreement and little misclassification between the two measures of vitamin D intake. Measurement error due to respondent memory is always a concern in epidemiologic studies and we were unable to evaluate this.

Sun exposure is another important source of vitamin D, yet, many studies of vitamin D and disease risk have focused only on vitamin D from diet/supplements. Optimal vitamin D status has

been proposed at 25 hydroxyvitamin D [25(OH)D] serum levels >30 ng/mL^{1,24} and it has been shown that intakes >12.5 µg/day^{25,26} are required to maintain optimal wintertime 25(OH)D levels in Northern populations, such as Canada. The mean total intake among all women in our study was only 9.7 µg/day, suggesting the potential for suboptimal serum 25(OH)D levels. There are two forms of vitamin D: vitamin D3 (from fatty fish, most supplements and fortified foods) and vitamin D2 (from plants). These forms of vitamin D may differ in biologic activity²⁷ and were not measured in this study, but we would suspect that most would be vitamin D3.

Many researchers have concluded that the current AIs are not sufficient to maintain optimal serum levels of 25(OH)D^{25,28} and the dietary reference intakes for vitamin D are under review.^{29,30} Considering the low proportion of women who met current AIs in this study, more work is needed to ensure that women are consuming sufficient vitamin D. Despite fortification differences between Canada and the US, there is relatively high agreement in vitamin D intake from food using a US FFQ before and after modification for Canadian values (and including fatty fish). Lower than recommended total vitamin D intakes were observed among our study participants which may negatively impact health.¹⁻³

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RÉSUMÉ

Objectifs : Mesurer et comparer l'apport alimentaire en vitamine D chez les femmes en Ontario à l'aide d'un questionnaire Block (É.-U., 1998) sur la fréquence de consommation de produits alimentaires (FCPA) avant et après avoir modifié ce questionnaire en fonction de l'enrichissement des aliments en vitamine D au Canada.

Méthode : Par composition aléatoire, nous avons créé un échantillon aléatoire de 3 471 Ontariennes (de 25 à 74 ans) stratifié selon l'âge. Nous avons appliqué à la FCPA les valeurs nutritives standard des États-Unis et une analyse des apports en vitamine D modifiée pour le Canada.

Résultats : L'apport alimentaire en vitamine D (analyse des nutriments au Canada) était de 5,3 ± 3,4 µg/jour (moyenne ± déviation sensible [DS]), et 45 % des femmes ont déclaré prendre des suppléments de vitamine D. Les apports totaux en vitamine D n'étaient conformes aux apports adéquats en vigueur (5, 10 et 15 µg/jour) que pour 62 %, 47 % et 28 % des femmes de 50 ans et moins, de 51 à 70 ans, et de 71 ans et plus, respectivement. Nous avons observé une correspondance relativement élevée entre les méthodes états-unienne et canadienne de mesure de la valeur nutritive des aliments en vitamine D (coefficient kappa pondéré = 0,74, IC de 95 % = 0,72-0,76). Les écarts dans les apports (états-unien moins canadiens) allaient de -5,0 µg/jour à +2,0 µg/jour (1^{er} au 99^e centile); cependant, l'écart moyen n'était que de -0,54 µg/jour (IC de 95 % = -0,58 à -0,50).

Conclusion : Des apports totaux en vitamine D inférieurs aux recommandations ont été observés chez les participantes de l'étude, ce qui pourrait avoir des incidences négatives sur l'état de santé des femmes. Le fait de tenir compte de l'enrichissement des aliments au Canada et d'inclure les poissons gras a eu peu d'impact sur la mesure de l'apport alimentaire en vitamine D.

Mots clés : vitamine D; aliments enrichis; enquêtes nutritionnelles; femmes; Canada; États-Unis