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The vitamin D status of Canadians relative to the 2011 Dietary Reference Intakes: an examination in children and adults with and without supplement use[1–3]

Susan J Whiting, Kellie A Langlois, Hassanali Vatanparast, and Linda S Greene-Finestone

ABSTRACT

Background: The 2011 Dietary Reference Intakes (DRIs) for vitamin D use 25-hydroxyvitamin D [25(OH)D] concentrations to define vitamin D deficiency (<30 nmol/L), the Estimated Average Requirement (40 nmol/L), and the Recommended Dietary Allowance (RDA; 50 nmol/L). The Canadian population has not yet been assessed according to these recommendations.

Objective: We determined the prevalence of meeting DRI recommendations and the role of vitamin D supplement use among Canadians aged 6–79 y.

Design: Plasma 25(OH)D from a representative sample of Canadians in the Canadian Health Measures Survey–Cycle 1 (n = 5306) were used. Supplement use was assessed by household interview. Concentrations of 25(OH)D were compared in supplement users and nonusers by season and race.

Results: Overall, 5.4%, 12.7%, and 25.7% of the participants had 25(OH)D concentrations below the 30-, 40-, and 50-nmol/L cutoffs, respectively. In white Canadians, plasma 25(OH)D concentrations ranged from an undetectable percentage with concentrations <30 nmol/L in summer to 24.5% with concentrations <50 nmol/L in winter; the corresponding values ranged from 12.5% to 53.1% in nonwhite Canadians. Supplement users had significantly higher 25(OH)D concentrations than did nonusers, and no seasonal differences were found. In nonsupplement users, the prevalence of 25(OH)D concentrations <50 nmol/L in winter was 37.2% overall and was 60.7% in nonwhites.

Conclusions: One-quarter of Canadians did not meet the RDA, but the use of vitamin D supplements contributed to a better 25(OH)D status. Nonwhite Canadians had the highest risk of not achieving DRI recommendations. More than one-third of Canadians not using supplements did not meet the RDA in winter. This suggests that current food choices alone are insufficient to maintain 25(OH)D concentrations of 50 nmol/L in many Canadians, especially in winter. *Am J Clin Nutr* doi: 10.3945/ajcn.111.013268.

INTRODUCTION

Vitamin D status has been the focus of much research in the past decade. The circulating concentration of 25-hydroxyvitamin D [25(OH)D] is a well-established biomarker for total vitamin D exposure from food, supplements, and endogenous synthesis. The Institute of Medicine's 2011 Dietary Reference Intakes (DRIs) (1, 2) established reference levels for 25(OH)D based on bone health, as follows: concentrations <30 nmol/L are associated with a risk of deficiency, of 40 nmol/L are consistent with the Estimated Average Requirement (EAR) of 400 IU, and of 50 nmol/L are consistent with the Recommended Dietary Allowance (RDA) of 600 to 800 IU for those aged ≥1 y. The intake set as EARs and RDAs assume minimal sun exposure. Most Canadians live above 42 °N, and it is expected that there are 5–6 mo of little or no sun-induced synthesis of vitamin D (3, 4); several studies have indicated low concentrations of 25(OH)D during wintertime in Canadians (5–7). However, other factors such as cloud cover, ozone cover, and atmosphere may affect ultraviolet B penetration, and contradictory findings regarding latitude are also evident (8).

In 2007–2009, Canada reported for the first time national data on vitamin D status using plasma concentrations of 25(OH)D for ages 6–79 y (9) in the Canadian Health Measures Survey (CHMS). The prevalence of meeting commonly used 25(OH)D cutoffs was examined, and <5% had concentrations <27.5 nmol/L, ≈10% had concentrations <37.5 nmol/L, and 65% had concentrations <75 nmol/L (9). Seasonal differences in 25(OH)D were modest (9).

In 2004, Canadians reported ingesting, on average, 208–300 IU vitamin D/d from foods (10)—amounts insufficient to meet the current RDA of 600 to 800 IU (1, 2). The prevalence of vitamin D supplement users has not been reported at the national level. In older Canadians in British Columbia, 60% reported vitamin D supplement use (11). In a representative study of Canadians aged ≥35 y, supplement use >400 IU was associated with the lowest prevalence of 25(OH)D concentrations <50 nmol/L (5). For older adults to achieve 25(OH)D concentrations >75 nmol/L in Quebec, Canada, supplement intake was necessary (12).

Concentrations of 25(OH)D in the CHMS showed a significant U-shaped distribution in which children aged 6–11 y and adults aged 60–79 y had higher 25(OH)D concentrations than did adolescents and younger adults (9). The latter finding was unexpected

[1] From the College of Pharmacy and Nutrition, University of Saskatchewan, Saskatoon, Canada (SJW and HV); the Health Analysis Division, Statistics Canada, Ottawa, Canada (KAL); and the Science Integration Division, Public Health Agency of Canada, Ottawa, Canada (LSG-F).

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[3] Address correspondence to SJ Whiting, College of Pharmacy and Nutrition, University of Saskatchewan, Saskatchewan, Canada. E-mail: susan.whiting@usask.ca.

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because older adults had the lowest 25(OH)D concentrations in some studies (13, 14), in part because of a decreased ability to synthesize vitamin D cutaneously (15). Vitamin D concentrations differed considerably by racial background, consistent with other Canadian studies (5, 16). The risk of vitamin D deficiency and inadequacy, however, has not been shown in a sample of Canadian children and adults by race.

This study aimed to determine the prevalence of Canadians meeting the 2011 DRI cutoffs of 30, 40, and 50 nmol/L by season and self-reported ethnic origin in the CHMS—a 2007–2009 national survey with wide age representation. We sought to determine vitamin D supplement use, assess its contribution to achieving DRIs, and examine seasonal differences in 25(OH)D among supplement users and nonusers in Canadians by age, sex, and skin pigmentation.

SUBJECTS AND METHODS

Data and methods

Data for this study are from the 2007–2009 CHMS. The CHMS is the most comprehensive, direct health measures survey ever conducted in Canada. The data in this report were collected over 24 mo in what is now called Cycle 1. Direct physical measures were collected for the household population aged 6–79 y. The survey consisted of 2 parts: *1*) an in-home interview to gather information on sociodemographic characteristics, health behaviors, nutrition, and medication and supplement use; and *2*) a subsequent visit to a mobile examination center for a series of direct measurements of height and weight, blood pressure, and physical fitness and for collections of urine and blood samples. The blood samples, taken by a certified phlebotomist, were used to measure a variety of substances and metabolites, including plasma 25(OH)D. Respondents unable to visit the mobile examination center were given the option of having the direct measurements taken in their home (17). Additional information about the CHMS is available in previously published reports (17–20).

Sampling plan

The sample used in this analysis consisted of 5306 respondents (2566 males and 2740 females), representing 28.2 million Canadians aged 6–79 y from all regions throughout the 2 y of data collection. Of the households selected to participate in the CHMS, 69.6% agreed. From these respondent households, 88.3% responded to the household questionnaire; of these household respondents, 84.9% reported to the mobile examination center for the direct physical measures. At the national level, the response rate was 51.7%. This overall response rate was not the result of multiplying the household and person response rates, because 2 persons were selected in some households (20). Residents of Indian reserves, institutions, Crown lands, and certain remote regions as well as full-time members of the Canadian Forces were excluded from the survey. Data were collected over a 2-y period (from March 2007 to February 2009) at 15 sites across the 5 regions of Canada: Atlantic provinces (Newfoundland and Labrador, Prince Edward Island, Nova Scotia, New Brunswick), Quebec, Ontario, the Prairies (Manitoba, Saskatchewan, Alberta; includes Yellowknife), and British Columbia (includes Whitehorse) (18). Although not every province/territory had a collection site, sites were chosen to represent the Canadian population from east to west, with larger and smaller population densities, and were ordered to take account of seasonality by region and temporal effects (18). The CHMS sample represents ≈96% of the Canadian population (28.2 million) aged 6–79 y from all regions living between latitude 43°N and 52°N.

The ages of respondents were grouped according to the CHMS sampling plan: 6–11, 12–19, 20–39, 40–59, and 60–79 y (18). Data on age were collected at both the household interview and the mobile examination center visit. For this study, the respondent's age was defined based on the latter. The sample included women who were pregnant or lactating (n = 30), of whom two-thirds used a vitamin D supplement. Because of the small sample size, these women were not treated separately in the analyses.

25(OH)D analysis

With the use of the LIAISON 25-Hydroxyvitamin D TOTAL assay (Diasorin Ltd, Stillwater, MN), plasma 25(OH)D concentrations were measured with a chemiluminescence assay. The lower and upper detection limits are 10 and 375 nmol/L, respectively. Plasma samples had been previously stored at −20°C. The analyses were performed singly rather than as paired samples. In-house Diasorin testing estimated the assay CVs (%) with runs as 3.2–8.5% and between runs as 6.9–12.7%. Health Canada laboratory samples were consistently within these limits on the basis of external quality controls from BioRad and Diasorin. The Health Canada laboratory participates in the proficiency vitamin D testing through DEQAS (Vitamin D external quality assurance scheme, United Kingdom) and has received annual certification of proficiency since joining DEQAS in 2005. Detailed information on the collection and measurement of plasma 25(OH)D in the CHMS can be found in the *Vitamin D Reference Laboratory Standard Operating Procedures Manual* at www.statcan.gc.ca.

Respondents who refused to have their blood drawn, did not have enough blood drawn, or had medical reasons for not having their blood drawn (eg, chemotherapy) were excluded (n = 298). Individuals whose vitamin D measurement was below the lower limit of detection (9.98 nmol/L) were assigned a value half of the lower limit (4.99 nmol/L) (21). Measured values were compared with cutoffs for 25(OH)D per the Institute of Medicine's recent definitions: <30 nmol/L indicates deficiency, and 40 and 50 nmol/L are consistent with the EAR and RDA, respectively (1, 2). We also examined the prevalence of plasma 25(OH)D concentrations >150 nmol/L, which is the concentration used to set the Tolerable Upper Intake Level (UL) for vitamin D (1, 2).

Supplement use

The household questionnaire asked all respondents about their use of medications within the past month, including prescriptions, over-the-counter medications, and health products and herbal remedies. Subjects provided a drug identification number (DIN) for each reported medication, when possible. In addition, respondents reported the last time they had taken that medication, with a range of responses, including today, yesterday, within the past week, within the past month, and >1 mo ago. At the clinic visit, respondents were again asked about their medication and supplement use; those reported at the household visit were verified, and any new ones were recorded. Because 25(OH)D

concentrations take ≈2 mo to equilibrate (22), this analysis was limited to supplements reported at the household interview and taken within 1 mo of that interview.

To identify DINs associated with vitamin D, the Licensed Natural Health Product Database (LNHPD) and the Drug Product Database (DPD) from Health Canada were consulted. Both active and inactive drugs registered in the DPD as of 3 August 2010 with the active ingredient codes "4924" (vitamin D_2), "4922" (vitamin D_3), and "703" (vitamin D) were retained (n = 1648). Similarly, all health products and herbal remedies registered in the LNHPD as of 4 August 2010 that contain vitamin D were included (n = 1699), with the exception of topical creams. Items from the DPD and LNHPD were merged and assessed for quality. All dosages reported in IUs were converted to micrograms for consistency. Any item with an ingredient quantity >25 μg was inspected for potential errors and cross verified with its potency value (if provided) or product name. In instances in which the daily dose was a range (eg, 1–2 tablets/d), the lower end was imputed. In the few instances in which quantities could not be determined, these products were assigned a value of 80 IU after examination of the vitamin D content of similar preparations, usually calcium supplements.

Associated factors

Concentrations of 25(OH)D are associated with skin pigmentation, but the CHMS did not collect information on skin pigmentation per se. For this analysis, racial background was used as a proxy. The CHMS asked respondents to choose among an extensive list of backgrounds; those who indicated "white" were categorized as such. Because of the low sample size of nonwhite respondents, the racial background was defined in only 2 categories: white and nonwhite. Seasonality was based on the date respondents visited the mobile examination center, where the blood draw took place —November to March or April to October— consistent with studies based on the National Health and Nutrition Examination Survey (NHANES) in the United States (23). This categorization represents the "winter" period, during which cutaneous synthesis of vitamin D is unlikely in Canada, and the "summer" period, during which cutaneous synthesis is likely (3, 4).

Statistical analysis

The unweighted sample sizes of participants with valid plasma 25(OH)D concentrations are shown by sex and age group elsewhere (*see* Supplementary Table 1 under "Supplemental data" in the online issue). Weighted sample sizes are also provided in this table. Unweighted sample sizes and weighted percentages of subjects by race, sex, and age group are also shown elsewhere (*see* Supplementary Table 2 under "Supplemental data" in the online issue). Descriptive statistics (frequencies, means) were used to estimate plasma 25(OH)D concentrations by cutoff concentration, supplement use, age group, sex, racial background, and month of blood collection. The analyses were conducted in SUDAAN (version 10 software; Research Triangle Institute, Research Triangle Park, NC). All estimates were based on data weighted to represent the Canadian population aged 6–79 y. Variance estimates (95% CIs) were calculated, and t tests were used to test differences between prevalence and mean estimates. In all analyses, we used the bootstrap weights provided with the data to account for the complex sampling design. Given the 11 df available for variance estimation, denominator df = 11 was specified in each SUDAAN procedure statement. Statistical significance was defined as a P value <0.05.

RESULTS

To determine the vitamin D status of Canadians, we examined 25(OH)D concentrations relative to the 2011 IOM cutoffs defined for risk of deficiency (<30 nmol/L), for the EAR (40 nmol/L), and for the adequacy of almost everyone (50 nmol/L) year-round and during winter and summer (**Table 1**). Year-round prevalence rates for 25(OH)D concentrations <30, <40 and <50 nmol/L were 5.4%, 12.7%, and 25.7%, respectively. For each cutoff analyzed, some significant differences were found for sex but no significant differences were found between summer and winter. In the determination of those at risk of deficiency (<30 nmol/L), some estimates of prevalence were too low to detect because of the extreme variability or small sample sizes. However, the prevalence of deficiency was as high as 12% in adolescents in winter. For 25(OH)D concentrations <40 nmol/L, values ranged from 4.3% for children aged 6–11 y in summer to 24.8% for men aged 20–39 y in winter. For concentrations <50 nmol/L, values ranged from a low of 10.5% (males aged 6–11 y year-round) to as high as 45.3% (men aged 20–39 y in winter).

Forty persons in the sample (representing 240,791 Canadians) had 25(OH)D concentrations >150 nmol/L, which is the upper range for the concentration of 25(OH)D used to set the UL for vitamin D (1, 2). Of these 40 persons, 46.7% (CI: 22.5, 72.5) took a supplement and 53.3% (CI: 27.5, 77.5) did not. The low number of subjects prevented further analysis.

To further characterize prevalence below cutoffs, race was included in the analysis (**Table 2**). Nonwhites accounted for ≈20% of the sample. Canadians who self-reported as white had lower prevalence estimates below all 3 cutoffs for every age and sex group year-round compared with Canadians self-classified as nonwhite. Differences were particularly striking for deficiency estimates (<30 nmol/L), for which the prevalence of nonwhite Canadians was 16.3%. In contrast, the prevalence for white Canadians was <5% for all age and sex groups. A prevalence <40 nmol/L was 8.7% for white Canadians year-round. Again, nonwhite Canadians had much higher prevalences: 30.5% (year-round), 33.0% (winter), and 28.3% (summer). Within this group, those aged 12–59 y had higher percentages of concentrations less than the cutoff of <40 nmol/L than did the youngest and oldest age groups. For nonwhite adolescents, ≈50% did not have 25(OH)D concentrations >40 nmol/L in winter. Overall, one-fifth of white Canadians had 25(OH)D concentrations <50 nmol/L; 25% had 25(OH)D concentrations <50 nmol/L in winter. Nonwhite Canadians again had much higher prevalences (51.4% year-round), with little difference between winter (53.1%) and summer (49.8%).

In 2007–2009, 31% of Canadians aged 6–79 y reported taking at least one supplement containing vitamin D in the previous month. Approximately 95% of all supplements consumed were in the vitamin D_3 form. No difference in supplement use was reported between white (31.9%) and nonwhite (27.3%) Canadians. Among supplement users, 69.3% took ≤400 IU, which was the dose taken by most children, adolescents, and young adults. Only a small percentage (3.2%) of the total population had

TABLE 1
Distribution of subjects by 25-hydroxyvitamin D [25(OH)D] concentrations, season, and sex in a household population aged 6–79 y from Canada, 2007–2009[1]

25(OH)D concentration	Year-round			Winter			Summer		
	n	%	95% CI	*n*	%	95% CI	*n*	%	95% CI
<30 nmol/L									
Ages 6–79 y	270	5.4	4.0, 7.4	139	7.2[2]	3.8, 13.3	131	4.3[2]	2.4, 7.8
Female	126	3.8[2,3]	2.6, 5.5	62	4.9[2]	2.5, 9.2	64	—	—
Male	144	7.1	4.9, 10.1	77	—	—	67	5.5[2]	3.3, 9.0
<40 nmol/L									
Ages 6–79 y	615	12.7	10.0, 16.1	300	16.0[2]	10.7, 23.2	315	10.6[2]	6.8, 16.3
Female	295	10.5[3]	7.9, 13.7	134	12.6[2]	7.7, 19.9	161	9.1[2,3]	5.9, 13.7
Male	320	15.0	11.3, 19.5	166	19.7[2]	12.0, 30.7	154	12.1[2]	7.5, 19.1
Age group									
6–11 y	44	—	—	25	—	—	19	4.3[2]	2.2, 8.3
12–19 y	112	14.1[2]	9.2, 21.1	63	19.5[2]	10.2, 34.0	49	10.6[2]	5.9, 18.4
20–39 y	192	15.8	11.2, 21.8	102	19.3[2]	12.1, 29.2	90	13.0[2]	6.2, 25.2
40–59 y	176	13.3	10.1, 17.2	82	17.0[2]	11.4, 24.5	94	11.2[2]	6.6, 18.4
60–79 y	91	7.9	6.2, 10.0	28	—	—	63	8.2	5.9, 11.3
<50 nmol/L									
Ages 6–79 y	1274	25.7	21.4, 30.7	569	31.0	23.7, 39.3	705	22.4	15.9, 30.6
Female	621	22.8[3]	18.8, 27.3	260	26.6[3]	20.6, 33.7	361	20.2	14.8, 27.0
Male	653	28.7	23.6, 34.4	309	35.7	26.2, 46.5	344	24.5[2]	16.5, 34.7
Ages 6–11 y	131	14.1[2]	8.4, 22.8	60	—	—	71	13.1[2]	6.9, 23.4
Female	84	17.9[2,3]	9.9, 30.2	38	—	—	46	16.3[2]	9.2, 27.1
Male	47	10.5[2]	6.4, 16.9	22	—	—	25	—	—
Ages 12–19 y	231	26.3	19.1, 35.0	122	34.2[2]	22.0, 49.0	109	21.0[2]	12.4, 33.3
Female	102	20.0[2,3]	13.5, 28.4	48	24.23[3]	16.5, 33.9	54	17.5[2]	9.2, 30.8
Male	129	32.1	23.1, 42.7	74	42.0[2]	25.5, 60.6	55	24.5[2]	14.0, 39.4
Ages 20–39 y	341	31.0	24.4, 38.5	176	37.9	28.4, 48.4	165	25.5[2]	16.1, 37.8
Female	162	25.5[3]	19.7, 32.4	82	31.3[3]	23.7, 39.9	80	20.3[2,3]	12.5, 31.2
Male	179	36.4	28.6, 44.9	94	45.3	32.6, 58.6	85	30.0[2]	18.6, 44.6
Ages 40–59 y	349	26.3	21.6, 31.7	149	32.6	25.3, 40.8	200	22.8	15.6, 32.1
Female	171	25.0	20.3, 30.4	67	30.1	23.0, 38.3	104	21.7	15.8, 29.1
Male	178	27.7	22.1, 34.1	82	35.6	25.7, 47.0	96	23.8[2]	14.2, 37.1
Ages 60–79 y	222	18.9	14.8, 23.9	62	14.4	10.4, 19.8	160	21.2	14.6, 29.6
Female	102	17.3	12.4, 23.5	25	10.8[3]	7.7, 15.0	77	20.2[2]	13.3, 29.6
Male	120	20.7	16.4, 25.9	37	18.0[2]	12.1, 26.0	83	22.2[2]	14.8, 31.9

[1] Data are from the 2007–2009 Canadian Health Measures Survey. (17–20). —, estimate not provided because of extreme sample variability or small sample size.
[2] Interpret with caution (high sampling variability: CV ≥16.6 and <33.3).
[3] Significantly different from males within the same age and time period ($P < 0.05$).

supplement intakes >1000 IU, used mostly by older subjects (≥40 y), most of whom were female (data not shown). We examined the association between supplement use and 25(OH)D concentrations by season (**Table 3**). Overall, in both winter and summer, supplement users had higher 25(OH)D concentrations than did nonusers. This was apparent for almost all age and sex groups in winter. Supplements had less of an effect on 25(OH)D concentrations in summer; only the older age-sex groups clearly showed the effect of higher plasma concentrations with supplement use during this season, ie, those aged 20–39 y (but not males and females, separately), females aged 40–59 y, and men and women aged 60–79 y. Children and teenagers had similar concentrations in summer, whether or not supplements were consumed. Seasonal differences in 25(OH)D concentrations were not apparent among supplement users.

To determine the extent to which some Canadians were not meeting the DRI-consistent cutoffs, prevalences <30, 40, and 50 nmol/L were examined under various situations known to affect 25(OH)D concentrations (**Table 4**). First, an examination of the relations with and without supplement use showed that nonusers had a prevalence of 6.6%, 15.6%, and 30.4% below the cutoffs, respectively. Some differences between males and females were found. Prevalences below the cutoffs for nonusers were at least twice those for supplement users (2.9%, 6.4%, and 15.4%, respectively; $P < 0.05$). Because of unstable estimates, we were only able to compare supplement users and nonusers in winter only for the 50 nmol/L cutoff: more than one-third of nonusers had 25(OH)D concentrations <50 nmol/L, approximately twice that of supplement users ($P < 0.05$). Finally, an examination of nonwhite Canadians during the winter showed that those not using supplements had the highest prevalence below the 50 nmol/L cutoff. Supplement use (except among males) was associated with a reduced prevalence below cutoffs by 40–50% ($P < 0.05$).

DISCUSSION

In the recent revision of the DRIs for vitamin D, the IOM established new reference concentrations of 25(OH)D to facilitate

TABLE 2
Distribution of subjects by 25-hydroxyvitamin D [25(OH)D] concentrations, sex, time of year, and race in a household population aged 6–79 y from Canada, 2007–2009[1]

	Year-round						Winter						Summer					
	White			Nonwhite[2]			White			Nonwhite[2]			White			Nonwhite[2]		
25(OH)D concentration	*n*	%	95% CI	*n*	%	95% CI	*n*	%	95% CI	*n*	%	95% CI	*n*	%	95% CI	*n*	%	95% CI
<30 nmol/L																		
Ages 6–79 y	127	3.0[3,4]	2.0, 4.4	143	16.3[3]	11.1, 23.2	52	3.3[4]	2.6, 4.2	87	20.4[3]	10.8, 35.2	75	—	—	56	12.5[3]	8.1, 19.0
Female	55	2.1[3,4]	1.1, 3.9	71	11.7	8.1, 16.5	20	2.4[3,4]	1.1, 4.9	42	13.5[3]	7.7, 22.8	35	—	—	29	9.7[3]	5.1, 17.8
Male	72	3.8[3,4]	2.6, 5.7	72	20.3[3]	11.8, 32.8	32	4.4[3]	2.6, 7.4	45	—	—	40	3.5[3,4]	2.0, 6.1	27	14.7[3]	8.4, 24.3
Age group																		
6–11 y	<10	—	—	10	—	—	0	0.0	0.0, 0.0	<10	—	—	<10	—	—	<10	—	—
12–19 y	20	3.8[3,4]	2.0, 6.9	39	17.5[3]	8.5, 32.6	<10	—	—	30	31.6[3]	14.9, 55.1	11	—	—	<10	—	—
20–39 y	32	—	—	48	17.8[3]	11.8, 26.0	14	2.7[3]	1.5, 4.8	31	—	—	18	—	—	17	—	—
40–59 y	45	3.9[3,4]	2.5, 6.0	39	20.1[3]	10.1, 36.0	17	4.2[3]	2.7, 6.5	18	—	—	28	3.7[3]	1.9, 7.3	21	—	—
60–79 y	28	2.2[3]	1.3, 3.7	<10	—	—	12	3.0[3]	1.4, 6.0	<10	—	—	16	—	—	<10	—	—
<40 nmol/L																		
Ages 6–79 y	355	8.7[4]	6.6, 11.3	260	30.5	25.7, 35.8	150	11.0[4]	8.8, 13.8	150	33.0[3]	21.8, 46.6	205	7.3[3,4]	4.6, 11.4	110	28.3	19.8, 38.5
Female	161	7.3[4]	5.1, 10.3	134	25.4	20.6, 31.0	57	8.3[3,4]	4.7, 14.4	77	27.1	19.1, 36.8	104	6.7[3,4]	3.9, 11.1	57	23.7[3]	15.9, 33.7
Male	194	10.0[4]	7.3, 13.6	126	35.0	27.8, 43.0	93	13.9[4]	9.7, 19.5	73	39.3[3]	20.1, 62.5	101	7.9[3,4]	5.0, 12.3	53	31.7	21.8, 43.7
Age group																		
6–11 y	12	—	—	32	15.4[3]	8.0, 27.5	<10	—	—	21	—	…	<10	—	—	11	10.1[3]	4.8, 20.3
12–19 y	48	7.8[3,4]	4.7, 12.6	64	35.5[3]	23.6, 49.4	20	—	—	43	48.2[3]	24.9, 72.2	28	7.0[3,4]	3.8, 12.6	21	24.6[3]	12.7, 42.1
20–39 y	102	10.0[4]	7.0, 14.2	90	35.1	25.6, 45.9	48	13.5[3,4]	9.0, 19.7	54	34.0[3]	20.9, 50.0	54	7.6[3]	3.8, 14.4	36	—	—
40–59 y	116	9.6[4]	6.7, 13.5	60	32.1[3]	20.4, 46.5	54	13.1	9.3, 18.2	28	32.5[3]	15.2, 56.4	62	7.8[3,4]	4.1, 14.1	32	31.7[3]	17.4, 50.5
60–79 y	77	7.3[4]	5.9, 9.0	14	13.0[3]	8.2, 20.0	24	6.7[3]	3.2, 13.3	<10	—	—	53	7.6	5.5, 10.4	10	—	—
<50 nmol/L																		
Ages 6–79 y	823	19.9[4]	16.0, 24.3	449	51.4	46.4, 56.4	332	24.5	19.9, 29.8	237	53.1	41.7, 64.2	491	17.2[3,4]	11.7, 24.4	212	49.8	42.2, 57.5
Female	384	16.9[4]	13.5, 21.1	235	50.0	43.6, 56.3	140	19.5	15.5, 24.2	120	51.2	38.9, 63.2	244	15.4[3,4]	10.5, 22.1	115	48.7	41.6, 55.9
Male	439	22.8[4]	18.2, 28.2	214	52.6	44.9, 60.3	192	29.9	22.9, 37.9	117	55.2[3]	32.6, 75.8	247	18.9[3,4]	12.5, 27.4	97	50.7	39.5, 61.8
Age group																		
6–11 y	56	8.4[3,4]	5.1, 13.4	75	32.4[3]	17.9, 51.4	17	—	—	43	47.7[3]	25.9, 70.5	39	10.4[3]	5.4, 18.9	32	—	—
12–19 y	133	19.1[4]	13.2, 26.8	97	49.6	36.9, 62.3	61	24.9[3,4]	15.0, 38.3	61	60.1[3]	33.7, 81.8	72	15.6[3,4]	8.6, 26.5	36	40.4[3]	23.5, 60.0
20–39 y	197	22.0[4]	16.6, 28.5	143	61.2	53.6, 68.2	99	30.3[4]	24.5, 36.8	77	57.5	41.2, 72.2	98	16.1[3,4]	10.2, 24.5	66	65.7	46.9, 80.6
40–59 y	248	21.6[4]	17.0, 27.2	101	50.5	38.0, 63.0	100	27.4[4]	20.8, 35.0	49	53.8[3]	33.0, 73.4	148	18.6[3,4]	12.1, 27.6	52	48.0[3]	30.3, 66.1
60–79 y	189	17.2[4]	13.4, 21.9	33	33.7[3]	21.4, 48.7	55	14.0	10.2, 19.0	<10	—	—	134	18.8[4]	12.9, 26.6	26	43.4[3]	23.2, 66.1

[1] Data from the 2007–2009 Canadian Health Measures Survey (17–20). —, estimate not provided because of extreme sampling variability or small sample size.
[2] Nonwhite includes Chinese, South Asian, black, Filipino, Latin American, Southeast Asian, Arab, West Asian, Japanese, Korean, Aboriginal, and other racial backgrounds.
[3] Interpret with caution (high sampling variability: CV $\geq$ 16.6 and $<$ 33.3).
[4] Significantly different from nonwhites within the same time period, $P < 0.05$ (*t* test).

TABLE 3
Mean 25-hydroxyvitamin D concentrations by supplement use, month of blood collection, sex, and age group in a household population aged 6–79 y from Canada, 2007–2009[1]

	Winter						Summer					
	Supplement use			No supplement use			Supplement use			No supplement use		
	n	Mean	95% CI	*n*	Mean	95% CI	*n*	Mean	95% CI	*n*	Mean	95% CI
		nmol/L			*nmol/L*			*nmol/L*			*nmol/L*	
Ages 6–79 y	696	74.4[2]	66.2, 82.6	1271	58.6	53.1, 64.1	896	77.1[2]	72.5, 81.7	2443	67.1	61.3, 72.9
Female	408	76.1[2]	71.2, 81.1	596	60.0	55.1, 64.9	553	78.4[2]	73.8, 83.0	1183	68.7[3]	63.8, 73.5
Male	288	72.0[2]	58.9, 85.2	675	57.3	50.3, 64.4	343	75.3[2]	67.6, 82.9	1260	65.9	59.1, 72.7
Ages 6–11 y	119	83.1[2]	71.4, 94.8	221	67.9	56.0, 79.7	140	79.1	69.4, 88.8	423	75.1	68.0, 82.2
Female	56	87.6[2]	74.4, 100.8	116	64.2	48.7, 79.6	73	76.8	65.3, 88.2	205	73.1	64.8, 81.5
Male	63	79.2	67.0, 91.3	105	72.2	62.6, 81.8	67	81.7	72.0, 91.4	218	76.7	70.2, 83.3
Ages 12–19 y	72	69.5[2]	63.0, 75.9	305	58.4	50.1, 66.6	80	72.5	61.5, 83.5	488	73.6[3]	66.0, 81.3
Female	38	68.3	58.4, 78.2	134	60.8	53.9, 67.6	41	69.2	56.1, 82.3	243	76.8[3]	69.3, 84.3
Male	34	71.3[2]	63.4, 79.1	171	56.7	47.0, 66.4	39	76.0	67.2, 84.7	245	70.4	59.6, 81.2
Ages 20–39 y	134	70.3[2]	59.3, 81.4	336	55.7	49.9, 61.6	142	82.2[2]	67.5, 97.0	552	65.9	57.0, 74.7
Female	87	80.2[2]	65.6, 94.7	179	57.6	51.0, 64.1	90	86.3	65.5, 107.1	294	70.3[3]	62.4, 78.1
Male	47	56.9	50.4, 63.3	157	53.9	45.0, 62.8	52	77.3	56.1, 98.5	258	62.4	51.9, 72.8
Ages 40–59 y	164	70.0	58.7, 81.2	270	59.5	52.9, 66.0	219	74.0[2]	65.8, 82.3	565	65.6	60.8, 70.5
Female	108	66.8	60.4, 73.2	120	61.7	55.1, 68.2	140	74.9[2]	68.2, 81.6	274	65.8	61.8, 69.8
Male	56	74.7	50.2, 99.2	150	57.1	48.7, 65.6	79	72.8	57.6, 88.1	291	65.4	59.0, 71.9
Ages 60–79 y	207	83.8[2]	78.1, 89.6	139	62.7	59.1, 66.3	315	77.9[2]	72.8, 83.0	415	64.0	60.0, 68.0
Female	119	84.4[2]	79.6, 89.2	47	61.9	53.5, 70.4	209	79.3[2]	73.7, 84.9	167	61.3	57.4, 65.1
Male	88	83.1[2]	69.6, 96.6	92	63.1	59.9, 66.2	106	75.3[2]	67.3, 83.3	248	66.2	61.6, 70.8

[1] Data from the 2007–2009 Canadian Health Measures Survey (17–20). There were no significant differences between winter and summer ($P < 0.05$) in supplement users (*t* test).
[2] Significantly different from no supplement use within same season, $P < 0.05$ (*t* test).
[3] Significantly different from no supplement use in winter, $P < 0.05$ (*t* test).

the assessment of vitamin D status and adequacy for individuals and populations (1, 2). Most Canadians live above 42° N; therefore, the CHMS report, in which 25(OH)D concentrations averaged 67.7 nmol/L, suggests reasonably good status considering their 5–6 mo of winter, when cutaneous synthesis of vitamin D is reduced (9). We found a very low year-round prevalence of 25(OH)D concentrations <30 nmol/L (5.4%); 12.7% had a prevalence of <40 nmol/L and 25.7% <50 nmol/L. However, these estimates mask concentrations of 25(OH)D, which appear to be affected by season and by skin pigmentation.

In our initial examination of CHMS data (9), an average seasonal difference of only 6 nmol/L was found between summer and winter. Our current data indicate that the seasonal effect on 25(OH)D concentrations in Canadians is blunted by supplement use. Furthermore, little or no seasonal effect was observed in nonwhite Canadians, which suggests that sun exposure in summer is not contributing to vitamin D synthesis as much as for white Canadians. Synthesis of vitamin D in darker pigmented skin takes a longer time, and synthesis is dependent on an adequate area of bare skin exposed to ultraviolet B radiation (24). Others have reported similar findings. When measured in the fall, a time of maximum solar synthesis of vitamin D in Canadians, adults of European ancestry had 25(OH)D concentrations that averaged close to 75 nmol/L compared with concentrations of 50 nmol/L for those of East Asian and South Asian ancestry living in Toronto (43°N) (16). Total dietary vitamin D was not associated with 25(OH)D. Similarly, in a large Canadian population study, dietary intake of vitamin D from foods alone by Canadians who are not of European origin was reported as similar to that of white Canadians (10), and the prevalence of supplement use was similar. Given similar dietary intakes of vitamin D and supplement use, the main reason why Canadians not of European origin have lower 25(OH)D concentrations is likely because they are unable to make sufficient vitamin D from casual sun exposure.

The small percentage of Canadians with a risk of vitamin D deficiency [25(OH)D < 30 nmol/L] was not appreciably higher in winter (7%); however, for nonwhite Canadians in winter, the prevalence was 20%. Close to 20% of Canadians were of visible minority in the 2006 census (25). Having 1 in 5 nonwhite Canadians at risk of rickets and osteomalacia is a public health concern. Cases of rickets have been described in Canada, despite there being no centralized registry (26). Recent recommendations on vitamin D intake are mainly based on skeletal effects of vitamin D and risk of rickets and osteomalacia; this study's findings identify nonwhites as a population particularly at risk of deficiency.

In the survey period of 2007 to 2009, 31% of Canadians aged 6–79 y reported the use of a vitamin D supplement. Our analysis suggests that current supplement use by Canadians has contributed considerably to the lower prevalences of 25(OH)D concentrations below DRI-based cutoffs year-round in the total population. In winter, the prevalence of 25(OH)D < 50 nmol/L among Canadians varied greatly, from 19% in supplement users to 37% in nonusers. Our findings concur with those of the Canadian Multicentre Osteoporosis Study (CaMos) (5). In that study, 20% of adults aged ≥35 y had 25(OH)D concentrations <50 nmol/L, and supplement use blunted the effect of season. Among those taking >400 IU vitamin D/d, a 25(OH)D concentration <50 nmol/L was ≤10%, regardless of season, which confirms the role of supplementation in reducing the likelihood

TABLE 4
Distribution of subjects taking a supplement, by 25-hydroxyvitamin D [25(OH)D] concentrations and sex in a household population aged 6–79 y from Canada, 2007–2009[1]

25(OH)D concentration	Supplement use			No supplement use		
	n	%	95% CI	*n*	%	95% CI
Total sample						
<30 nmol/L						
Ages 6–79 y	34	2.9[2,3]	1.6, 5.3	236	6.6	4.8, 9.0
Female	18	—	—	108	4.9[2,4]	3.3, 7.3
Male	16	—	—	128	8.0	5.5, 11.3
<40 nmol/L						
Ages 6–79 y	86	6.4[2,3]	4.3, 9.4	529	15.6	12.0, 20.0
Female	51	5.4[2,3]	3.4, 8.5	244	13.4	9.6, 18.2
Male	35	7.8[2,3]	4.0, 14.4	285	17.4	13.0, 23.1
<50 nmol/L						
Ages 6–79 y	215	15.4[3]	11.8, 19.8	1059	30.4	24.7, 36.8
Female	119	12.7[3,4]	9.9, 16.2	502	28.5	22.9, 34.9
Male	96	19.2[3]	13.5, 26.5	557	32.0	25.7, 39.0
Winter only						
<30 nmol/L						
Ages 6–79 y	17	—	—	122	9.0[2]	4.6, 16.8
Female	<10	—	—	55	7.1[2]	3.6, 13.6
Male	10	—	—	67	—	—
<40 nmol/L						
Ages 6–79 y	41	—	—	259	20.9[2]	13.5, 30.9
Female	22	—	—	112	17.9[2]	10.7, 28.3
Male	19	—	—	147	23.8[2]	13.1, 39.2
<50 nmol/L						
Ages 6–79 y	103	19.3[2,3]	12.6, 28.5	466	37.2	26.2, 49.7
Female	55	15.7[3]	11.4, 21.1	205	33.7	23.0, 46.4
Male	48	24.5[2]	12.0, 43.5	261	40.5	27.6, 54.8
Nonwhite in winter only[5]						
<30 nmol/L						
Ages 6–79 y	13	—	—	74	22.1[2]	11.2, 38.8
Female	<10	—	—	37	16.9[2]	9.0, 29.4
Male	<10	—	—	37	—	—
<40 nmol/L						
Ages 6–79 y	24	—	—	126	38.1[2]	24.8, 53.4
Female	12	—	—	65	33.5[2]	22.0, 47.3
Male	12	—	—	61	43.3	21.5, 68.0
<50 nmol/L						
Ages 6–79 y	44	36.3[2,3]	21.1, 54.9	193	60.7	47.0, 72.8
Female	23	29.7[2,3]	16.8, 46.9	97	59.8	44.1, 73.8
Male	21	42.3[2]	17.7, 71.4	96	61.6[2]	34.5, 83.0

[1] Data from the 2007–2009 Canadian Health Measures Survey (17–20). —, estimate not provided because of extreme sampling variability or small sample size.
[2] Interpret with caution (high sampling variability: CV $\geq$ 16.6 and $<$ 33.3).
[3] Significantly different from no supplement use, $P < 0.05$.
[4] Significantly different from males, $P < 0.05$.
[5] Nonwhite includes Chinese, South Asian, black, Filipino, Latin American, Southeast Asian, Arab, West Asian, Japanese, Korean, Aboriginal, and other racial backgrounds.

of below-target 25(OH)D concentrations. In the CHMS, we were unable to measure the contribution of vitamin D from food sources, but found previously that 25(OH)D concentrations differed by 13 nmol/L in those who reported drinking milk more than once per day compared with those who drank milk less than once per day (9). The Canadian diet contains a limited number of fortified foods; fluid milk (including milk-like plant-based beverages) and margarine are mandatory sources (27). The average intake of vitamin D, measured in the national Canadian Community Health Survey in 2004, was 250 IU from foods alone, mainly from milk (10). Despite this low intake, nearly 75% of Canadians were achieving a 25(OH)D concentration of 50 nmol/L. This suggests that ambient sunlight exposure has made a significant contribution to their 25(OH)D concentrations.

Our 2007–2009 data indicate that, even with current levels of food fortification and sun exposure, 25% of Canadians had 25(OH)D concentrations that were less than the 50 nmol/L concentration recommended for adequate vitamin D. Close to 33% of Canadians took a vitamin D supplement, which was associated with higher prevalences of adequacy. Several campaigns have been established to encourage supplement use by Canadians. In 2007, Health Canada recommended that all adults aged >50 y take a 400-IU vitamin D supplement. Also in 2007, the Canadian Cancer Society recommended that Canadian adults take a 1000-IU vitamin D supplement in winter. The 2002 Osteoporosis Canada recommendation in effect at the time of the study (but since revised) was 800 IU for adults aged >50 y for bone health. Whereas supplements can be effective, it has been shown that individuals with a low income who are probably at need are less likely to use them (28).

This study had some limitations. The use of vitamin D supplements was determined by a positive response to use within a recent time period. Persons who took vitamin D within the past month were categorized as "users," although there was no information on the frequency or duration of use. Additionally, the dosage on the product was assumed to be the usual dosage taken because quantity was not assessed. Some respondents may have been misclassified or dosages may have been under- or overestimated. Despite this, the large and significant differences in 25(OH)D between those categorized as supplement users and nonusers and their consistency with findings in the literature (5) suggest that the method had reasonable validity. In CHMS Cycle 1, logistical and cost constraints in using mobile examination centers restricted the number of collection sites to 15 (17–20). The sample size of various age and sex categories, especially when dividing by season and race, made it difficult to examine more specific subgroups in relation to vitamin D status. As future CHMS cycles become available, exploration of other interrelations might be possible when data from cycles are combined. It was not possible to analyze different races and ethnicities in Canada beyond white and nonwhite. The CHMS did not collect data from Aboriginal peoples living on-reserve who may be at higher risk of vitamin D deficiency.

Comprehensive dietary assessment is not part of the CHMS design; therefore, we could not take into account vitamin D intakes from food. Specific to the analysis of vitamin D status, there were no questions regarding the use of tanning beds or travel to southern destinations, which is common for some Canadians in winter. The overall response rate in the CHMS was 51.7%. Survey weights were adjusted to ensure that the sample was representative of the target population based on certain sociodemographic characteristics. Health status, however, was not accounted for; therefore, it is possible that vitamin D status differed between respondents and nonrespondents.

In conclusion, whereas vitamin D deficiency was low in the population, one-fourth of Canadians had 25(OH)D concentrations that were <50 nmol/L. In winter (November to March),

with minimal sun exposure, more than one-third of Canadians not taking supplements had 25(OH)D concentrations <50 nmol/L. Furthermore, when coupled with nonwhite race, the proportion of Canadians with 25(OH)D concentrations <50 nmol/L increased to almost two-thirds. Supplement use contributed to better vitamin D status and a higher prevalence of 25(OH)D concentrations ≥50 nmol/L and attenuated the effect of season on vitamin D status. Future research should examine determinants of vitamin D supplement use among Canadians and its variation across ethnic groups.

We dedicate this manuscript to the memory of our colleague Nick Hidiroglou.

The authors' responsibilities were as follows—SJW, KAL, and LSG-F: designed the research; KAL: accessed the CHMS data; SJW, KAL, and LSG-F: analyzed the data; SJW, KAL, HV, and LSG-F: wrote the manuscript; and SJW: had primary responsibility for the final content. All authors read and approved the final manuscript. None of the authors had a conflict of interest.

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