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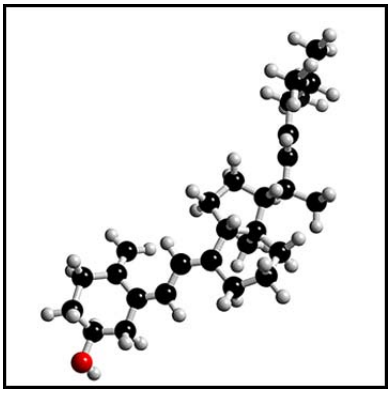
Vitamin D status of Canadians as measured in the 2007 to 2009 Canadian Health Measures Survey



by Kellie Langlois, Linda Greene-Finestone, Julian Little, Nick Hidiroglou and Susan Whiting

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Abstract

Background
Vitamin D deficiency is a global health problem, but little is known about the vitamin D status of Canadians.

Data and methods
The data are from the 2007 to 2009 Canadian Health Measures Survey, which collected blood samples. Descriptive statistics (frequencies, means) were used to estimate 25-hydroxyvitamin D [25(OH)D] concentrations among a sample of 5,306 individuals aged 6 to 79 years, representing 28.2 million Canadians from all regions, by age group, sex, racial background, month of blood collection, and frequency of milk consumption. The prevalence of deficiency and the percentages of the population meeting different cut-off concentrations were assessed.

Results
The mean concentration of 25(OH)D for the Canadian population aged 6 to 79 years was 67.7 nmol/L. The mean was lowest among men aged 20 to 39 years (60.7 nmol/L) and highest among boys aged 6 to 11 (76.8 nmol/L). Deficiency (less than 27.5 nmol/L) was detected in 4% of the population. However, 10% of Canadians had concentrations considered inadequate for bone health (less than 37.5 nmol/L) according to 1997 Institute of Medicine (IOM) Standards (currently under review). Concentrations measured in November-March were below those measured in April-October. White racial background and frequent milk consumption were significantly associated with higher concentrations.

Interpretation
As measured by plasma 25(OH)D, 4% of Canadians aged 6 to 79 years were vitamin D-deficient, according to 1997 IOM standards (currently under review). Based on these standards, 10% of the population had inadequate concentrations for bone health.

Key words
sun exposure, milk, ethnicity

Authors
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The Canadian Health Measures Survey (CHMS), launched by Statistics Canada in 2007 in partnership with Health Canada and the Public Health Agency of Canada, collected direct physical measures of health and wellness from a nationally representative sample of Canadians. It is the most comprehensive direct health measures survey undertaken in Canada at the national level. A fundamental aspect of the CHMS is the collection of blood and urine samples,[1] which were analyzed for chronic and infectious diseases, environmental toxins, and nutritional biomarkers, including glucose, cholesterol, calcium, and vitamin D. This study examines 25-hydroxyvitamin D [25(OH)D] concentrations in the Canadian population aged 6 to 79 years and factors shown to affect vitamin D status.

Vitamin D deficiency is a worldwide health problem.[2] Vitamin D promotes calcium and phosphorous absorption, which is necessary to build and maintain bones and teeth, and is also a transcription factor in most cells in the body.[3,4] Although the optimal concentration for overall health is currently under debate, lower levels of vitamin D have been associated with a greater risk of rickets in children or osteomalacia in adults;[5] increased risk of fractures,[6] falls,[7] breast cancer,[8] colorectal cancer and adenoma;[9] poor immunity;[4] and cardiovascular[10] and other diseases such as multiple sclerosis.[11]

Vitamin D activity in the body results from two conversions of the parent compound cholecalciferol, which is made in the skin in the presence of ultraviolet B (UVB) radiation.[3] Another source is ingestion of preformed

cholecalciferol (often called vitamin D_3) or ergocalciferol (vitamin D_2), the latter being formed when certain fungi or yeasts are irradiated with UVB. The major circulating form of vitamin D in the blood is 25-hydroxyvitamin D [25(OH)D]. Plasma (or serum) 25(OH)D concentration is generally considered to be the best metabolite to reflect vitamin D status.[3] It represents the sum of 25(OH)D from diet and endogenous synthesis.

The determinants of vitamin D status are multifactorial and include environmental, physiological and personal characteristics. Some environmental factors can decrease synthesis of vitamin D in the skin, for example, reduced exposure to sunlight, winter season, sunscreen use, being indoors, and clothing coverage.[2] The physiologic factors associated with lower vitamin D status include pregnancy and lactation, and elevated body mass index/adiposity.[2,3] The personal characteristics include age,[12-14] level of ingestion of dietary sources,[15,16] and skin pigmentation.[2,15,16] Factors that may lead to lower vitamin D concentrations among Canadians in particular include living at a high latitude (which lessens the time for vitamin D synthesis),[17,18] a lack of dietary intake,[15,16] and for some people, darker skin pigmentation.[15,16]

The extent to which Canadians' vitamin D status has been measured and evaluated is limited. Several regional studies have reported relatively low concentrations in a high percentage of Canadian children,[17,19] adults,[18,20] pregnant women and their infants,[21-23] Aboriginal populations,[15,23] and the very old and institutionalized.[24] A small study found a disparity between Canadians of European descent and those from East Asia or South Asia, with the latter having very low levels of vitamin D in winter.[16]

Data and methods

Data for this study are from 2007 to 2009 Canadian Health Measures Survey (CHMS). This survey collected direct physical measures for the household population aged 6 to 79 years. The survey consisted of two parts: 1) an in-home interview to gather information on sociodemographic characteristics, health behaviours, environmental factors and nutrition, and 2) a subsequent visit to a mobile examination centre[25] for a series of direct measurements of height and weight, blood pressure, physical fitness, and collection of urine and blood samples. The blood samples, taken by a certified phlebotomist, measured a variety of substances and metabolites, including plasma 25(OH)D. Respondents unable to visit the mobile examination centre were given the option of having the direct measurements taken in their home.[1] Additional information about the CHMS is available in previously published reports and online from Statistics Canada's website.[1,25-27]

Sampling plan

Of the 8,772 dwellings selected in the CHMS, 6,106 agreed to participate for a household response rate of 69.6%. From these respondent households, 7,483 people were selected to participate in the survey, 6,604 of whom agreed to respond to the questionnaire for a response rate of 88.3%. Of these, 5,604 reported to the mobile examination centre for physical measurements, for a response rate of 84.9%. At the national level, the response rate was 51.7%. This overall response rate is not the result of multiplying the household and person response rates, since two people were selected in some households.[28]

Residents of Indian reserves, Crown lands, certain remote regions, and institutions, and full-time members of the Canadian Forces were excluded from the survey. Over two years, data were collected at 15 sites across the five 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).[25] 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.[25] Approximately 97% of the Canadian population is represented.

25-hydroxyvitamin D analysis

Using the LIAISON 25-Hydroxyvitamin D TOTAL assay (Diasorin, Ltd.), plasma 25(OH)D levels were measured by a chemiluminescence assay (CLIA). The lower and upper detection limits are 10 nmol/L and 375 nmol/L, respectively. Plasma samples had been previously stored at -20°C. Analyses were performed singly rather than as paired samples. In-house Diasorin testing estimated the assay %CVs with runs as 3.2% to 8.5% and between runs as 6.9% to 12.7%. Health Canada laboratory samples were consistently within these limits, using 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, UK) and has received annual certification of proficiency since joining DEQAS in 2005. For more detailed information on the collection and measurement of plasma 25(OH)D in the CHMS, refer to the *Vitamin D Reference Laboratory Standard Operating Procedures Manual* at www.statcan.gc.ca.

Respondents with hemophilia or who had chemotherapy in the previous four weeks were excluded from blood collection. Also, in some cases, the respondent did not provide enough blood for the vitamin D measure (tubes were collected in priority order). 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).[29]

Measured values were compared with cut-offs for 25(OH)D. However, there is considerable controversy about what concentration of circulating 25(OH)D is optimum for health. The Institute of Medicine (IOM) is currently updating the 1997 Dietary Reference Intakes for vitamin D,[5] as new evidence indicated

the need for revision.[30] The 1997 Dietary Reference Intakes were based on achieving a concentration of at least 27.5 nmol/L, values below which have been associated with vitamin D deficiency (defined as high risk of rickets in children or osteomalacia in adults).[5] Concentrations below 37.5 nmol/L are considered inadequate for bone health, based on the IOM recommendations,[5] although these are currently under review. For this analysis, vitamin D deficiency was defined as a concentration below 27.5 nmol/L. Inadequacy for bone health was defined as a concentration below 37.5 nmol/L. Nonetheless, there is growing consensus that much higher concentrations, specifically, those above 75 nmol/L, are desirable for overall health and disease prevention.[3,31-33] Consequently, this cut-off was also examined. Concentrations above 220 nmol/L correspond to intakes for adults at a proposed "no observed adverse effects levels" of 250 µg (10,000 IU) of vitamin D per day.[34] Concentrations exceeding 375 nmol/L pose a risk of adverse effects and have a potential for toxicity.[35] These cut-offs were also evaluated.

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 non-White respondents, racial background was defined in only two categories: White and Other.

A proxy for the effect of seasonality was based on the date respondents visited the mobile examination centre—November to March or April to October—consistent with studies based on the National Health and Nutrition Examination Survey (NHANES) in the United States.[36] This categorization represents a period during which cutaneous synthesis of vitamin D is unlikely in Canada, and a period during which cutaneous synthesis is likely.[37]

During the household interview, respondents were asked how much time each day they usually spend in the sun on "a typical weekend or day off from work/school in the summer months" between 11 a.m. and 4 p.m. For this study, daily sun exposure was defined in three categories: less than 30 minutes, 30 minutes to less than one hour, and one hour or more.

Respondents were asked how often they drink milk or enriched milk substitutes or use them on cereal. They were categorized as consuming milk less than once a day, once a day, or more than once a day.

Age was grouped according to the CHMS sampling plan: 6 to 11 years, 12 to 19 years, 20 to 39 years, 40 to 59 years, and 60 to 79 years.[25] Data on age were collected at both the household interview and the mobile examination centre visit. For this study, the respondent's age was defined based on the latter.

Statistical analysis

The sample used in this analysis consisted of 5,306 respondents (2,566 males and 2,740 females), representing 28.2 million Canadians aged 6 to 79 years from all regions throughout the two years of data collection. Respondents who refused to have their blood drawn, did not have enough blood drawn, or had medical reasons for not having their blood drawn (for example, chemotherapy) were excluded (n=298). The unweighted sample sizes with valid plasma 25(OH)D concentrations are presented by sex and age group in Appendix Table A.

Descriptive statistics (frequencies, means) were used to estimate plasma 25(OH)D concentrations by age group, sex, racial background, month of blood collection, and frequency of milk consumption (Appendix Table B). Data on other factors such as dietary supplements and sunscreen use will be examined in subsequent analyses. The prevalence of deficiency and the percentages of the population meeting different concentrations of 25(OH)D were assessed.

All estimates were based on data weighted to represent the Canadian population aged 6 to 79 years. Variance estimation (95% confidence intervals) and significance testing (chi-square or t-test) on differences between estimates were calculated using the bootstrap weights provided with the data, which account for the complex sampling design. Significance was defined as a p-value of < 0.05. The Bonferroni adjustment method was used in cases of multiple comparisons (for example, age groups). Analyses were conducted in SUDAAN v.10.

Results

The mean concentration of 25(OH)D among Canadians aged 6 to 79 years was 67.7 nmol/L (Table 1). Mean concentrations ranged from a low of 60.7

Table 1
Mean 25-hydroxyvitamin D concentrations, by age group and sex, household population aged 6 to 79 years, Canada, 2007 to 2009

Age group and sex	Mean	95% confidence interval	
	Mean nmol/L	from	to
Total 6 to 79 years	**67.7**	**65.3**	**70.1**
Male	65.7*	62.5	68.9
Female	69.7	67.8	71.7
6 to 11 years	**75.0[c d]**	**70.3**	**79.7**
Male	76.8[b c d e]	72.9	80.7
Female	73.1	67.0	79.1
12 to 19 years	**68.1**	**63.8**	**72.4**
Male	65.6*[a]	60.8	70.4
Female	70.8	65.8	75.9
20 to 39 years	**65.0[a e]**	**61.0**	**69.0**
Male	60.7*[a e]	55.3	66.1
Female	69.5	65.8	73.2
40 to 59 years	**66.5[a e]**	**63.8**	**69.2**
Male	66.0[a]	62.1	69.8
Female	67.1[e]	65.0	69.2
60 to 79 years	**72.0[c d]**	**69.4**	**74.5**
Male	70.5[a c]	67.5	73.6
Female	73.3[d]	70.3	76.4

* significantly different from estimate for females in same age group
[a] significantly different from estimate for 6 to 11 years of same sex
[b] significantly different from estimate for 12 to 19 years of same sex
[c] significantly different from estimate for 20 to 39 years of same sex
[d] significantly different from estimate for 40 to 59 years of same sex
[e] significantly different from estimate for 60 to 79 years of same sex
Source: 2007 to 2009 Canadian Health Measures Survey.

nmol/L among men aged 20 to 39 years to a high of 76.8 nmol/L among boys aged 6 to 11 years. For both sexes, the pattern of 25(OH)D concentrations by age group followed a U-shape: highest among children and seniors, and lowest at ages 20 to 39 years. Concentrations were significantly higher among females than males overall and at ages 12 to 39 years.

An estimated 4.1% of the population (5.2% of males and 3.0% of females) had concentrations below 27.5 nmol/L, indicating that they were deficient in vitamin D (Table 2). The highest prevalence of deficiency was among men aged 20 to 39 years (6.8%).

Just over 10% of Canadians (12.9% of males and 8.3% of females) had concentrations below 37.5 nmol/L—levels considered inadequate for bone health. This means that about 90% of the population (87.1% of males and 91.7% of females) had adequate concentrations for bone health (according to IOM recommendations, which are currently under review). Females were more likely than males to have adequate concentrations, overall and at ages 20 through 59 years. Boys aged 6 to 11 years were significantly more likely than older males to have adequate concentrations.

Approximately one-third of the population (33.0% of males and 37.8% of females) had concentrations above 75 nmol/L, the level proposed for optimal health. The percentage was highest at ages 6 to 11 years (48.6%) and ages 60 to 79 years (44.7%); it was lowest at ages 20 to 39 years (29.5%). Males and females were equally likely to meet this level, except at ages 20 to 39 years among whom the percentage of women was significantly higher than the percentage of men (36.3% versus 22.9%).

Fewer than 0.5% of the population had concentrations over 220 nmol/L, and no one in the CHMS sample was above the potentially toxic concentration of 375 nmol/L (data not shown).

White racial background tended to be associated with high concentrations of 25(OH)D (Table 3). The mean difference between racial groups was approximately 19 nmol/L; the smallest difference was among women aged 60 to 79 years (7.1 nmol/L), and the largest, among women aged 20 to 39 years (26.6 nmol/L).

Mean 25(OH)D concentrations varied by the month when the blood sample was taken (Table 3). Concentrations tended to be higher among people whose blood

Table 2
Percentage of household population aged 6 to 79 years meeting 25-hydroxyvitamin D concentration cut-offs, by age group and sex, Canada, 2007 to 2009

	Below 27.5 nmol/L			Below 37.5 nmol/L			Equal to or above 37.5 nmol/L			Above 75 nmol/L		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
Age group and sex	%	from	to	%	from	to	%	from	to	%	from	to
Total 6 to 79 years	**4.1[E]**	**2.9**	**5.8**	**10.6**	**8.2**	**13.6**	**89.4**	**86.4**	**91.8**	**35.4**	**32.0**	**38.9**
Female	3.0*[E]	2.0	4.4	8.3*	6.1	11.3	91.7*	88.7	93.9	37.8	34.8	40.8
Male	5.2[E]	3.4	7.8	12.9	9.7	16.9	87.1	83.1	90.3	33.0	27.6	38.9
6 to 11 years	**F**	**...**	**...**	**F**	**...**	**...**	**95.6**	**91.2**	**97.9**	**48.6[bcd]**	**41.7**	**55.5**
Female	F	...	...	F	...	...	93.4	85.2	97.2	45.1	36.6	53.9
Male	F	...	...	F	...	...	97.8[bcde]	95.5	98.9	51.9[bcd]	45.0	58.7
12 to 19 years	**5.0[eE]**	**3.1**	**8.0**	**11.8[E]**	**7.4**	**18.4**	**88.2**	**81.6**	**92.6**	**35.2[a]**	**30.4**	**40.3**
Female	F	...	...	8.9[E]	4.7	16.2	91.1	83.8	95.3	35.3	28.7	42.6
Male	5.0[E]	2.8	8.9	14.5[E]	9.0	22.4	85.5[a]	77.6	91.0	35.0[ac]	29.2	41.3
20 to 39 years	**5.1[E]**	**3.1**	**8.2**	**12.7[E]**	**9.1**	**17.6**	**87.3**	**82.4**	**90.9**	**29.5[ae]**	**23.6**	**36.3**
Female	3.2[E]	1.7	6.2	9.7*[E]	6.1	15.0	90.3*	85.0	93.9	36.3*	29.0	44.4
Male	6.8[E]	3.7	12.4	15.7[E]	10.8	22.2	84.3[a]	77.8	89.2	22.9[abdeE]	16.2	31.4
40 to 59 years	**4.4[eE]**	**2.9**	**6.6**	**11.2**	**8.3**	**14.9**	**88.8**	**85.1**	**91.7**	**33.6[ae]**	**29.9**	**37.6**
Female	2.9*[E]	1.7	4.8	8.6*[E]	5.9	12.4	91.4*	87.6	94.1	34.1	30.6	37.8
Male	5.9[eE]	3.9	8.8	13.8[E]	9.8	19.0	86.2[a]	81.0	90.2	33.2[ac]	26.5	40.6
60 to 79 years	**2.1[bdE]**	**1.1**	**3.9**	**7.1**	**5.6**	**9.0**	**92.9**	**91.0**	**94.4**	**44.7[cd]**	**38.7**	**50.9**
Female	F	...	...	5.7[E]	4.0	8.1	94.3	91.9	96.0	46.0	38.7	53.6
Male	2.4[dE]	1.3	4.2	8.7	6.2	12.0	91.3[a]	88.0	93.8	43.3[c]	36.3	50.5

* significantly different from estimate for females in same age group
[a] significantly different from estimate for 6 to 11 years of same sex
[b] significantly different from estimate for 12 to 19 years of same sex
[c] significantly different from estimate for 20 to 39 years of same sex
[d] significantly different from estimate for 40 to 59 years of same sex
[e] significantly different from estimate for 60 to 79 years of same sex
[E] interpret with caution (coefficient of variation 16.6% to 33.3%)
F estimate not provided because of extreme sampling variability or small sample size
... not applicable
Source: 2007 to 2009 Canadian Health Measures Survey.

Table 3
Mean 25-hydroxyvitamin D concentrations, by racial background, month of blood collection, milk consumption, age group and sex, household population aged 6 to 79 years, Canada, 2007 to 2009

	Racial background						Month of blood collection						Milk consumption								
	White			Other†‡			April to October			November to March†			More than once a day			Once a day			Less than once a day†		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
Age group and sex	Average nmol/L	from	to	Average nmol/L	from	to	Average nmol/L	from	to	Average nmol/L	from	to	Average nmol/L	from	to	Average nmol/L	from	to	Average nmol/L	from	to
Total 6 to 79 years	**71.2***	**68.8**	**73.7**	**52.3**	**49.1**	**55.5**	**70.0**	**65.6**	**74.4**	**64.1**	**60.3**	**67.9**	**75.0***	**72.5**	**77.5**	**68.1***	**65.3**	**71.0**	**62.7**	**60.5**	**64.9**
Female	73.3*	71.4	75.2	53.0	49.9	56.1	72.0*	68.6	75.4	66.3	63.3	69.3	75.8*	73.9	77.6	69.6*	67.2	72.1	65.9	63.4	68.3
Male	69.1*	65.7	72.6	51.6	47.3	56.0	68.1	62.4	73.7	61.7	56.5	66.9	74.2*	70.6	77.7	66.6*	61.8	71.4	59.7	56.8	62.5
6 to 11 years	**78.5***	**74.5**	**82.5**	**63.3**	**54.7**	**71.9**	**76.1**	**69.7**	**82.5**	**73.0**	**63.0**	**83.1**	**78.5***	**74.4**	**82.6**	**67.9**	**61.2**	**74.7**	**69.6**	**61.8**	**77.3**
Female	77.8*	73.0	82.6	56.7	46.0	67.4	74.1	66.7	81.6	71.4	58.7	84.1	77.5	72.4	82.6	64.0	55.0	73.0	70.1	58.9	81.2
Male	79.2*	74.8	83.6	69.4	61.8	76.9	77.9	72.2	83.6	74.8	66.3	83.3	79.4*	75.2	83.5	72.3	67.6	76.9	69.0	60.2	77.8
12 to 19 years	**72.2***	**68.3**	**76.1**	**54.8**	**48.3**	**61.2**	**73.5***	**67.5**	**79.4**	**60.1**	**53.4**	**66.9**	**74.1***	**69.0**	**79.3**	**68.1***	**62.0**	**74.3**	**58.9**	**52.8**	**65.0**
Female	76.9*	73.0	80.8	52.8	45.9	59.7	75.7*	69.9	81.4	62.4	56.8	68.1	77.7*	71.1	84.2	70.0*	63.3	76.8	62.8	56.2	69.3
Male	68.1*	62.9	73.2	56.8	47.4	66.3	71.2*	62.9	79.5	58.3	50.2	66.4	71.5*	65.1	78.0	65.7*	55.9	75.5	55.1	49.0	61.1
20 to 39 years	**70.2***	**65.7**	**74.7**	**47.8**	**44.2**	**51.3**	**69.3***	**62.2**	**76.4**	**59.6**	**54.8**	**64.4**	**71.3***	**65.4**	**77.3**	**67.9***	**62.8**	**73.0**	**58.4**	**53.9**	**62.9**
Female	75.5*	71.5	79.6	48.9	46.5	51.2	74.3*	67.5	81.1	64.2	59.7	68.8	73.8	68.4	79.2	71.5	65.8	77.1	64.9	58.0	71.8
Male	64.9*	58.4	71.4	46.8	41.2	52.4	65.0	56.0	74.1	54.6	47.8	61.3	68.8*	61.1	76.6	64.5*	57.3	71.7	52.3	47.2	57.3
40 to 59 years	**69.6***	**67.5**	**71.8**	**50.7**	**44.4**	**57.0**	**68.2**	**64.0**	**72.4**	**63.6**	**59.3**	**67.8**	**76.1***	**72.8**	**79.4**	**66.2**	**62.6**	**69.7**	**63.6**	**61.2**	**66.0**
Female	69.4*	67.8	71.1	52.4	46.5	58.2	69.2*	66.6	71.8	63.8	60.6	67.1	73.2*	67.2	79.2	66.6	63.5	69.8	65.2	62.4	67.9
Male	69.9*	66.4	73.4	49.4	41.9	57.0	67.3	61.0	73.6	63.2	56.5	69.9	79.5*	75.2	83.7	65.7	59.1	72.3	62.0	58.7	65.3
60 to 79 years	**73.1***	**70.4**	**75.8**	**62.4**	**54.6**	**70.2**	**70.2**	**66.4**	**74.0**	**75.5**	**72.7**	**78.3**	**78.9***	**75.5**	**82.2**	**72.5***	**69.5**	**75.5**	**68.8**	**65.4**	**72.2**
Female	74.1	70.7	77.4	67.0	54.9	79.1	71.1*	66.8	75.4	78.1	74.4	81.9	80.0*	75.3	84.7	73.5	67.1	79.9	69.8	65.9	73.8
Male	72.0*	68.9	75.2	57.2	52.2	62.3	69.2	64.9	73.4	72.9	67.2	78.7	77.2*	69.5	84.9	71.4	67.9	74.9	67.8	64.3	71.3

* significantly different from estimate for reference category of same age and sex
† reference category
‡ self-reported racial and cultural background, including Chinese, South Asian, Black, Filipino, Latin American, Southeast Asian, Arab, West Asian, Japanese, Korean, Aborigianal, and Other
Source: 2007 to 2009 Canadian Health Measures Survey.

was drawn in April-October rather than in November-March. The exception was women aged 60 to 79 years, who had higher concentrations in November-March. The percentage of Canadians in the adequate range (at least 37.5 nmol/L) was 91.8% in April-October, not significantly different from 85.6% in November-March. However, the percentage with concentrations above 75 nmol/L was significantly higher in April-October than in November-March: 38.6% versus 30.3% (data not shown).

Data on sun exposure during the summer indicate that people who reported an hour or less per day in the sun had lower 25(OH)D concentrations than did those who reported more than an hour (data not shown). However, because the CHMS determined sun exposure only for the summer months, the sample was not large enough to explore this relationship further.

The frequency of milk consumption tended to be positively related to 25(OH)D concentrations. People who consumed milk more than once a day had a mean concentration of 75 nmol/L versus 62.7 nmol/L among those who did so less than once a day (Table 3). The percentage of people consuming milk more than once a day declined with advancing age from about 65% of children aged 6 to 11 years to just over 20% of seniors aged 60 to 79 years (Appendix Table B).

Discussion

This study uses data from the 2007 to 2009 Canadian Health Measures Survey to examine the vitamin D status of Canadians aged 6 to 79 years. It is the first study in Canada based on direct measures of plasma 25(OH)D concentrations in a nationally representative sample. The comprehensiveness of the survey made it possible to examine several factors known to be associated with vitamin D status, including age, racial background and milk consumption.

Overall, 4% of Canadians had 25(OH)D concentrations considered deficient (less than 27.5 nmol/L). About 90% had concentrations meeting or exceeding 37.5 nmol/L, which is considered adequate for bone health by Institute of Medicine standards[5] (these standards are currently under review). Finally, a third of the population had concentrations above 75 nmol/L, the cut-off suggested in some studies[3,31-33,38] to be desirable for overall health and disease prevention.

Based on a cut-off of 25 nmol/L, countries around the world report a substantial portion of their populations as vitamin D-deficient.[2] In the United States, where measurements are taken in sunny months (summer in the northern states; winter in the southern states), the overall prevalence of concentrations under 27.5 nmol/L is about 5%.[38] In Canada, when limited to measurements taken in April-October, the prevalence of deficiency was just over 3%. Because of

methodological differences, comparisons with other countries should be made with caution.

In relation to values averaged over the entire year, almost 90% of the Canadian population met the 37.5 nmol/L adequacy cut-off for bone health. This is comparable to NHANES results for the United States.[39]

Children aged 6 to 11 years and seniors aged 60 to 79 years were most likely to be above the adequacy cut-offs, although the reasons for these higher levels probably differ. According to CHMS data, young children were more likely than older people to drink milk at least once a day (Appendix Table B). Older adults may be more likely to derive more vitamin D from supplements. This will be analyzed in a subsequent paper.

The necessity of classifying respondents into only two racial categories assumes that those identified as White have light skin pigmentation, and that the Other group consists of those with darker skin pigmentation. For the most part, this grouping revealed a significant difference, with the latter having lower 25(OH)D concentrations than the former. Data from the United States[13] show that non-Hispanic Black Americans have much lower concentrations than non-Hispanic White Americans across all age/sex groups, even when measured in the summer. A small Canadian study reported a similar finding,[16] but was not able to determine if lower concentrations among those with darker skin pigmentation (which was measured directly in that study) were confounded by their lower intake of vitamin D from foods and supplements.

The month in which the blood sample was taken for the CHMS was moderately associated with 25(OH)D concentrations, notably among females and people aged 12 to 39 years. (Factors such as supplement use may have prevented the emergence of a seasonal effect in some age groups.) Similarly, Vieth et al.[20] found higher concentrations in summer than in winter among women in the Toronto area. Rucker et al.[18] showed seasonal effects in adults aged 27 to 89 years, with lower concentrations in winter and fall than in spring and summer. Moreover, their results controlled for winter travel to southern destinations, an adjustment that could not be made to the CHMS data.

The frequency of milk consumption was significantly related to vitamin D status among Canadians of all ages; those consuming milk more than once a day had an average increase of 12 nmol/L, compared with those doing so less than once a day. This is similar to the 7 nmol/L difference among non-Hispanic White Americans aged 20 to 59 years who consumed fortified milk "often/sometimes," compared with "never or rarely."[36] Fortified milk consumption has been shown to be lower among Asians, First Nations and northern and southern Indians, likely because of dietary customs and/or a higher prevalence of lactose intolerance.[16] In fact, analyses of the CHMS data revealed that Canadians in the Other racial group consumed milk signficantly less frequently than did those classified as White ($p < 0.05$, data not shown). Nonetheless, the Other racial group shared the general pattern of higher 25(OH)D concentrations with more frequent milk consumption: 60.6 nmol/L for those consuming milk more than once a day, compared with 47.5 nmol/L for those reporting less than once a day ($p < 0.05$, data not shown).

Optimal concentrations of 25(OH)D have not been established, although some researchers have proposed 75 nmol/L as desirable for overall health and disease prevention.[3,31-33,38] Concentrations above that level are known to reduce fracture risk and improve calcium absorption.[6,7,40] Also, concentrations below 75 nmol/L are associated with a greater risk of breast cancer,[8] colorectal cancer and adenomas;[9] evidence of an association with other types of cancer is less clear.[41] Because of the uncertainty about optimal levels, this analysis examined concentrations in relation to higher cut-offs. More than a third (35%) of Canadians were above the 75 nmol/L cut-off; few other countries have reported a similarly high percentage.[2] Only 0.5% of Canadians had levels over 220 nmol/L, and no respondent to the CHMS had a concentration above 375 nmol/L, a potentially toxic level.[35]

This analysis has several limitations. Not all factors that may contribute to variations in 25(OH)D concentration were examined. The examination of interactions between potentially confounding factors was restricted by small sample sizes. No direct information on skin pigmentation was available, and information on milk consumption pertained to the frequency of consumption, not the amounts consumed. Not all regions were represented or compared by month of blood collection.

What is already known on this subject?

- Data from other countries report a high prevalence of vitamin D deficiency.
- Small studies have indicated that some Canadian subgroups have relatively low vitamin D concentrations.

What does this study add?

- This analysis examines vitamin D status in a nationally representative sample of Canadians.
- About 4% of Canadians aged 6 to 79 are vitamin D-deficient, and more than 10% do not have concentrations adequate for bone health. However, 35% are above the cut-off (75 nmol/L) recently suggested as desirable for overall health and disease prevention.
- Low milk consumption and non-White racial background are associated with lower plasma 25(OH)D concentrations.

Conclusion

This study identifies population groups that are likely to have lower concentrations of vitamin D and factors associated with vitamin D status. The factors related to low concentrations are winter season, racial backgrounds other than White, and less frequent intake of milk. Future analyses of CHMS data will investigate additional factors that may influence vitamin D concentrations, such as supplement consumption, body mass index, pregnancy, fish consumption and sunscreen use. ■

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Appendix

Table A
Unweighted sample sizes of participants with valid vitamin D concentrations, by age group and sex, household population aged 6 to 79 years, Canada, 2007 to 2009

Age group	Male	Female
Total 6 to 79 years	**2,566**	**2,740**
6 to 11 years	453	450
12 to 19 years	489	456
20 to 39 years	514	650
40 to 59 years	576	642
60 to 79 years	534	542

Source: 2007 to 2009 Canadian Health Measures Survey.

Table B
Selected characteristics of sample (weighted), by sex and age group, household population aged 6 to 79 years, Canada, 2007 to 2009

	Total 6 to 79			6 to 11 years			12 to 19 years			20 to 39 years			40 to 59 years			60 to 79 years		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
Characteristic	%	from	to	%	from	to	%	from	to	%	from	to	%	from	to	%	from	to
Male																		
Racial background																		
White	80.3	70.4	87.5	75.6	59.7	86.7	78.4	66.3	87.0	76.6	66.7	84.2	80.9	68.6	89.2	89.7	82.0	94.3
Other	19.7[E]	12.5	29.6	24.4[E]	13.3	40.3	21.6[E]	13.0	33.7	23.4[E]	15.8	33.3	19.1[E]	10.8	31.4	10.3[E]	5.7	18.0
Month of collection																		
November to March	37.3[E]	17.3	62.8	F	...	...	43.3[E]	20.5	69.4	41.7[E]	21.4	65.3	F	...	...	F	...	...
April to October	62.7[E]	37.2	82.7	64.9[E]	37.8	85.0	56.7[E]	30.6	79.5	58.3[E]	34.7	78.6	67.4[E]	38.9	87.1	64.6[E]	38.2	84.4
Milk consumption																		
Less than once a day	41.3	38.8	43.9	8.4	6.2	11.3	28.7	23.1	35.0	40.2	34.9	45.7	49.3	43.9	54.7	49.2	43.0	55.3
Once a day	32.8	30.6	35.0	24.0	19.5	29.1	20.4	16.1	25.6	34.9	31.4	38.5	35.5	30.9	40.4	35.1	28.7	42.0
More than once a day	25.9	23.2	28.8	67.6	61.3	73.3	50.9	44.5	57.3	25.0	18.8	32.3	15.2	11.4	20.0	15.8	11.4	21.3
Female																		
Racial background																		
White	82.4	74.3	88.4	76.2	61.6	86.4	75.4	66.6	82.4	77.5	69.0	84.2	86.3	77.1	92.2	89.7	83.6	93.7
Other	17.6[E]	11.6	25.7	23.8[E]	13.6	38.4	24.6	17.6	33.4	22.5[E]	15.8	31.0	13.7[E]	7.8	22.9	10.3[E]	6.3	16.4
Month of collection																		
November to March	40.0[E]	19.9	64.3	F	...	...	F	...	...	47.6[E]	23.4	72.9	39.1[E]	19.2	63.4	F	...	...
April to October	60.0[E]	35.7	80.1	61.5[E]	34.0	83.2	63.5[E]	36.3	84.2	52.4[E]	27.1	76.6	60.9[E]	36.6	80.8	68.4	45.2	85.0
Milk consumption																		
Less than once a day	40.0	37.5	42.7	9.2[E]	6.3	13.4	31.3	25.9	37.3	39.1	34.3	44.1	47.9	44.2	51.6	42.6	37.1	48.2
Once a day	33.6	31.9	35.4	27.7	22.9	33.1	28.5	24.0	33.5	34.6	30.3	39.1	34.3	29.8	39.1	35.9	30.7	41.4
More than once a day	26.3	23.4	29.4	63.0	57.6	68.1	40.2	34.5	46.2	26.3	21.7	31.6	17.8	13.5	23.2	21.6	18.5	25.0

[E] interpret with caution (high sampling variability; coefficient of variation 16.6% to 33.3%)
F estimate not provided because of extreme sampling variability or small sample size
... not applicable
Source: 2007 to 2009 Canadian Health Measures Survey.