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.. not available for a specific reference period
... not applicable
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0^s value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p} preliminary
^{r} revised
x suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E} use with caution
F too unreliable to be published
* significantly different from reference category ($p < 0.05$)

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Vitamin C status of Canadian adults: Findings from the 2012/2013 Canadian Health Measures Survey

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Abstract

Background: Although vitamin C is not produced in the body, it is important for many biochemical and physiological functions. Little is known about the current vitamin C status of Canadians. This study describes the correlates of vitamin C status in a nationally representative sample of adults.

Data and methods: Data are from the 2012/2013 Canadian Health Measures Survey. Plasma vitamin C (L-ascorbic acid) concentrations were measured among a fasting subsample of respondents aged 20 to 79 (n = 1,615). Vitamin C status, prevalence of deficiency (plasma vitamin C < 11 µmol/L), and use of vitamin C-containing supplements were estimated. Multivariate regression models were used to examine associations between vitamin C status and sociodemographic characteristics, smoking, body mass index, supplement use, and consumption of fruit juice and citrus fruit.

Results: The mean plasma vitamin C concentration of adults aged 20 to 79 was 53 µmol/L; fewer than 3% were vitamin C-deficient. Almost 22% took a vitamin C-containing supplement. Concentrations were lower among smokers and people who were obese, and higher among vitamin C supplement users and fruit juice and citrus fruit consumers. Multivariate models showed that supplement use was the strongest and most consistent predictor of vitamin C status; fruit juice and citrus fruit consumption were predictors only among populations with lower vitamin C concentrations (for example, smokers, obese).

Interpretation: Few Canadians were vitamin C-deficient. Smokers and people with a higher BMI were most at risk of lower vitamin C concentrations; concentrations were higher among supplement users and consumers of fruit juice and citrus fruit.

Key words: Ascorbic acid, BMI, citrus, deficient, fruit, obesity, smoking, supplement

Vitamin C, the common name for L-ascorbic acid, is a water-soluble vitamin that is not endogenously produced by humans.[1] Vitamin C has a number of biochemical and physiological functions, primarily as an enzyme cofactor (for example in the biosynthesis of collagen, carnitine, and catecholamines) and as an antioxidant.

The richest sources of vitamin C are fruits, vegetables, and nutritional supplements. However, in 2013, fewer than half (41%) of Canadians reported consuming vegetables and fruit five or more times per day.[2] Insufficient vitamin C intake over several weeks causes scurvy, which is characterized by fatigue, fragile capillaries and poor wound healing.[3] Severe deficiency is rare in developed countries,[4] but may occur among people whose diet does not provide at least 10 milligrams (mg) of vitamin C a day.[1] Vitamin C intake has also been investigated in the prevention of certain health conditions, including cardiovascular disease, stroke, neurological disorders and certain types of cancer.[3,5-7]

The Estimated Average Requirement (EAR) for vitamin C varies by age and sex (non-pregnant, non-lactating) from a low of 13 mg a day for children aged 1 to 3 to a high of 75 mg a day for men aged 19 or older. Because smoking increases oxidative stress and metabolic turnover of vitamin C, the requirement for smokers is 35 mg a day higher than the EAR for non-smokers.

The 2012/2013 Canadian Health Measures Survey collected biomarkers for vitamin C status. Based on those data, this study describes the vitamin C status (including deficiency) and determines its correlates in a nationally representative sample of Canadian adults. This is the first information that has been available about the vitamin C status of Canadians since the 1970/1972 Canada Nutrition Survey.[8]

Data and methods

The Canadian Health Measures Survey (CHMS) is an ongoing survey conducted by Statistics Canada in partnership with Health Canada and the Public Health Agency of Canada. The CHMS excludes residents of the three territories; full-time members of the Canadian Forces; and residents of reserves and other Aboriginal settlements, institutions, and certain remote regions. Approximately 96% of Canadians are represented.[9] Data for the 2012/2013 CHMS were collected at 16 sites across the country from January 2012 through December 2013 from respondents aged 3 to 79 in private households. The sites were ordered to take seasonality and temporal effects into account.[9] Detailed information about the CHMS is available in published reports.[10-12]

The survey involves an at-home interview to obtain information about socioeconomic characteristics, health, and lifestyle behaviours, followed by a visit to a mobile examination centre (MEC) for a series of direct physical measurements. At the MEC, blood is collected by a certified phlebotomist, and various biomarkers are measured. For some measures, including plasma vitamin C, a random subsample of respondents are required to fast for at least 10 hours before their MEC appointment. Children younger than 6, pregnant women, and people with diabetes are excluded from the fasting subsample.

Of the 8,120 households selected for the 2012/2013 CHMS, 6,017 (74.1%) provided information on household composition; of these, 3,425 were selected for the fasting subsample. In the respondent households, 4,271 people aged 6 to 79 were selected to participate; 3,773 (88.3%) completed the household questionnaire. A total of 2,981 respondents (79.0%) reported to the

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MEC; 2,532 of them had a valid fasting measure for plasma vitamin C. The combined response rate for vitamin C at the national level was 44.5%. This analysis focused on 20- to-79-year-olds with a valid plasma vitamin C concentration (n = 1,615).

Vitamin C analysis

Vitamin C in the form of L-ascorbic acid was determined via blood plasma. A lavender K2-EDTA vacutainer of whole blood specimen was collected by venipuncture, and immediately processed at the MEC. After addition of the 6% TCA preservative, aliquots of plasma were frozen, stored at -30°C, and shipped weekly on dry ice to Le Centre de Toxicologie du Québec (Quebec City) for analysis. Standardized procedures were developed for the collection of specimens, processing, and aliquoting, and for shipping biospecimens to the testing laboratory at the Institut national de santé publique du Québec (INSPQ).[13] To monitor the accuracy and precision of the analysis, blind quality control samples were included in each shipment. Samples were stored frozen (-80°C) until analysis, at which time they were thawed, and ascorbic acid was extracted from stabilized plasma using a dilution in alkaline medium. The supernatant was acidified and analyzed by high-performance liquid chromatography with tandem mass spectrometry (HPLC-MS-MS) in multiple-reaction monitoring mode with an electrospray ion source in negative mode.

The INSPQ, accredited under ISO 17025, followed standardized procedures developed for every assay and technique performed in its laboratory. Each analytical sequence contains reference materials, and the INSPQ also participated in an inter-laboratory comparison program. The inter-assay coefficient of variation (reproducibility) was less than 5%. Vitamin C (L-ascorbic acid) data were provided in micromoles per litre (µmol/L) rounded to two significant digits. Deficiency was defined as < 11 µmol/L.[1]

Covariates

Vitamin C concentrations were examined by sex, age group, racial background, household income, education, smoking status, and body mass index (BMI). Use of vitamin C-containing supplements and consumption of fruit juice and citrus fruit were also examined, as they have been shown to be the major vitamin C sources in the diet.[14]

Age (20 to 39, 40 to 59, and 60 to 79) was defined as of the MEC visit. Racial background was defined based on respondents' choice among an extensive list of racial and cultural backgrounds—those who indicated "white" were classified as such; all other backgrounds, including Aboriginal, were grouped in an "other" category.

Annual household income was classified by tertile: lower (less than $50,000), middle ($50,000 to less than $100,000), and higher ($100,000 or more). Education was dichotomized as college/university graduation versus less than college/university graduation. For respondents younger than 25, highest level of education in the household was used.

Self-reported smoking status was grouped into two categories: daily/occasional smokers and non-smokers (former and never smokers).

BMI was based on measured height and weight and calculated by dividing weight in kilograms by the square of height in metres (kg/m^2). In accordance with Health Canada guidelines, respondents were grouped into three categories: neither overweight nor obese (BMI less than 25), overweight (25 to less than 30), and obese (30 or more).[15]

Supplement use

At both the household and MEC interviews, respondents were asked if they had taken medications in the past month, including prescription drugs, over-the-counter medications or other health products including natural health products. Respondents reported the last time they had taken each medication: today, yesterday, within the last week, within the last month, and more than one month ago. Where possible, a drug identification number (DIN)/natural health product number (NPN) was also provided.

To identify vitamin C-containing supplements, data were extracted from Health Canada's Drug Product Database[16] and Licensed Natural Health Products Database[17]; products that contained vitamin C or ascorbic acid were retained. These DINs/NPNs were merged with those reported in the CHMS, and all vitamin C-containing supplements were flagged. For this analysis, supplement users were respondents who had taken a vitamin C-containing supplement within one month of the MEC interview.

Fruit juice, citrus fruit, and fruit drink consumption

During the household interview, respondents were asked if and how often they usually drink 100% pure "orange or grapefruit" juice, or "other" fruit juice; these were combined to capture all fruit juice. Similarly, consumption of fruit-flavoured drinks (not juice) and citrus fruits, such as oranges or grapefruits (fresh, frozen, canned) were reported. For this analysis, fruit juice and citrus fruit consumption were classified as: daily, at least once a week, at least once a month, and less than once a month or never. Fruit drink consumption was classified as: at least once a week, at least once a month, and less than once a month or never.

Statistical analysis

Since the data were not skewed, descriptive statistics (means) were used to estimate average concentrations of plasma vitamin C by sociodemographic and lifestyle characteristics. The prevalence of deficiency and of vitamin C-containing supplement use was also estimated. Cumulative distributions by selected covariates were calculated. Multivariate regression models examined associations between vitamin C concentrations and covariates that were related in bivariate analyses. The CHMS sampling methodology limited the analysis to 11 degrees of freedom. To include all covariates in the model simultaneously, models were

fitted separately for: smokers versus non-smokers; neither overweight nor obese versus overweight and versus obese; and vitamin C-containing supplement users versus non-users. Models controlled for sex, age, education, supplement use, smoking, BMI, fruit juice consumption, and citrus fruit consumption.

Table 1
Selected characteristics and mean plasma vitamin C concentrations, household population aged 20 to 79, Canada excluding territories, 2012/2013

	Prevalence			Mean vitamin C concentration		
		95% confidence interval			95% confidence interval	
Characteristic	%	from	to	µmol/L	from	to
Total	**100.0**	**...**	**...**	**53**	**50**	**56**
Sex						
Men	49.8	48.9	50.7	47*	43	52
Women†	50.2	49.3	51.1	59	55	63
Age group						
20 to 39	37.1	36.0	38.1	54	50	58
40 to 59	40.1	39.3	40.8	51*	47	55
60 to 79†	22.8	22.3	23.4	56	52	59
Race						
White†	75.9	63.3	85.3	54	51	56
Other	24.1	14.7	36.7	52	46	58
Household income tertile						
Lower	32.1	26.6	38.1	50	45	55
Middle	30.2	25.1	35.9	54	51	57
Higher†	37.7	33.1	42.5	55	51	59
Education						
Less than college/university graduation	31.0	26.2	36.3	46*	42	49
College/University graduation†	69.0	63.7	73.8	56	54	59
Smoking						
Daily/Occasional	20.0	16.0	24.7	45*	40	50
Non-smoker†	80.0	75.3	84.0	55	52	58
Body mass index						
Neither overweight nor obese†	38.1	32.1	44.5	58	54	63
Overweight	36.3	31.2	41.8	53	49	58
Obese	25.6	20.0	32.1	45*	42	49
Vitamin C-containing supplement use						
No†	78.2	71.1	83.9	49	46	52
Yes	21.8	16.1	28.9	69*	65	73
Fruit juice consumption						
Daily†	24.5	19.7	30.0	59	55	62
At least once a week	39.4	33.9	45.1	53	49	57
At least once a month	15.8	11.8	20.9	51*	46	57
Less than once a month or never	20.4	17.7	23.3	49*	43	55
Fruit drink consumption						
At least once a week†	9.2	7.4	11.4	49	43	56
At least once a month	8.2[E]	4.1	15.6	45	36	55
Less than once a month or never	82.6	75.5	88.0	54	52	57
Citrus fruit consumption						
Daily†	16.0	12.3	20.6	58	52	64
At least once a week	44.3	38.6	50.1	55	52	58
At least once a month	21.9	18.4	25.8	51*	46	56
Less than once a month or never	17.9	13.9	22.6	46*	39	52

... not applicable
[E] use with caution
*significantly different from reference category ($p < 0.05$)
† reference category
µmol/L = micromoles per litre
Source: 2012/2013 Canadian Health Measures Survey.

All analyses were conducted in SAS-callable SUDAAN version 11.0.1 using DDF = 11 in the procedure statements to account for the limited degrees of freedom in the CHMS. Because vitamin C data were collected from a subsample of CHMS respondents, special weights were used to represent the Canadian population. To account for the complex sampling design, variance estimation (95% confidence intervals) and significance testing (t-tests) on differences between estimates were calculated using the bootstrap weights provided with the data. Significance was defined as a p-value of < 0.05.

Results

The 1,615 respondents in the analytical sample represented 24.8 million Canadians aged 20 to 79. Half of them were men; 20% were daily or occasional smokers; and more than one-quarter were obese (Table 1). Nearly 22% reported having taken a vitamin C-containing supplement in the previous month; 25% drank fruit juice daily; and 16% ate citrus fruit daily.

Overall, fewer than 3% of Canadian adults had vitamin C deficiency. The prevalence of deficiency was higher among people who rarely or never consumed citrus fruit (13%), those who rarely or never drank 100% fruit juice (7%), and smokers (10%) (data not shown). None of those who took vitamin C-containing supplements were deficient.

The mean plasma vitamin C concentration of Canadians aged 20 to 79 was 53 µmol/L (Table 1). Women had significantly higher concentrations than did men. As well, concentrations were higher for older adults versus middle-aged adults, and for college/university graduates versus people with less formal education. Smokers and obese individuals tended to have relatively low concentrations. Users of vitamin C-containing supplements had mean concentrations that were 20 µmol/L higher than those of non-users. Concentrations decreased with less

frequent consumption of fruit juice and citrus fruit. No differences were apparent by race, household income, or fruit drink consumption. Results were similar when men and women were examined separately (data not shown).

Smokers had lower vitamin C concentrations than did non-smokers until about the 90th percentile of the cumulative distributions, at which point concentrations were comparable (Figure 1).

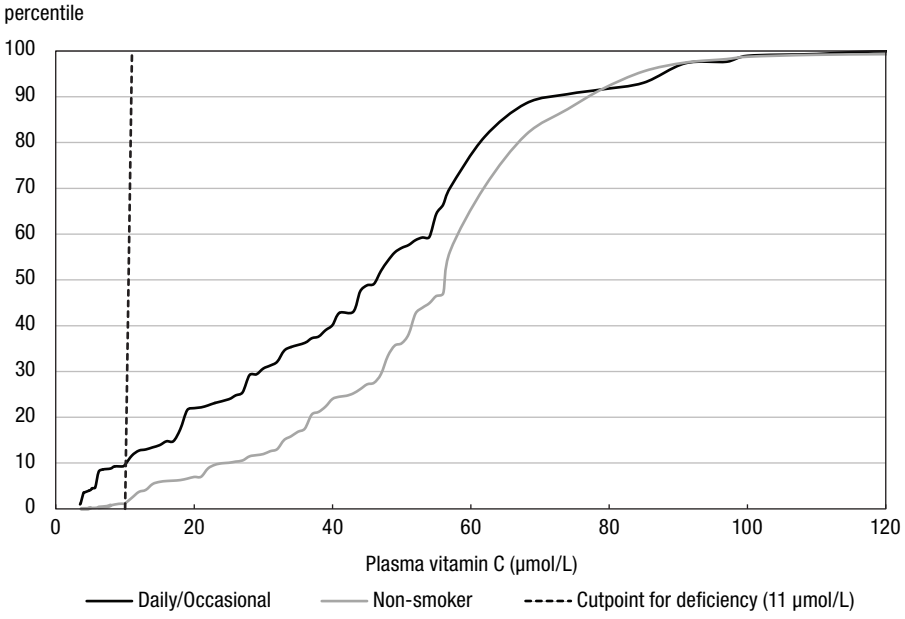
A gradient in vitamin C concentrations by BMI category was evident at all percentiles above the 10th in the cumulative distributions (Figure 2). Concentrations were low for overweight and obese individuals, compared with people who were neither overweight nor obese.

The largest difference in the cumulative distributions of concentrations was between users and non-users of vitamin C-containing supplements (Figure 3). At the 10th percentile, concentrations were three times higher for supplement users than for non-users; at the 95th percentile, concentrations were almost 100 µmol/L for supplement users, compared with about 80 µmol/L for non-users.

In all multivariate models except the overweight population, men had significantly lower vitamin C concentrations than did women (Table 2). Age was not associated with concentrations in any subgroup. Education was significant for non-smokers, people who were neither overweight nor obese, and non-supplement users—among these groups, concentrations were lower for those with less than college or university graduation.

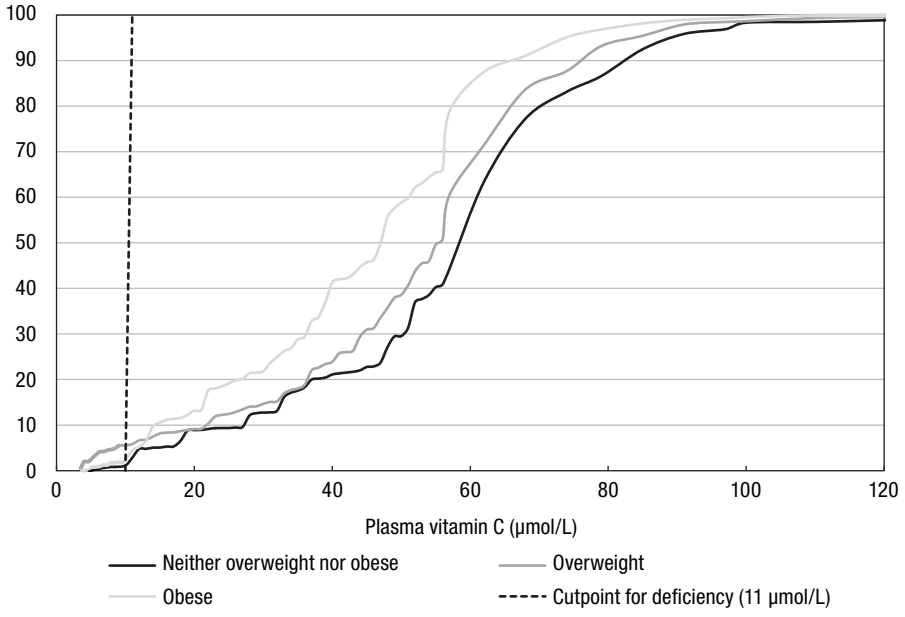
Results by smoking status were inconsistent (Table 2). For non-smokers, obesity was negatively associated with vitamin C concentrations. However, among smokers, obesity was not related to vitamin C status. Fruit juice consumption was not associated with vitamin C among non-smokers, but among smokers, more frequent fruit juice consumption was related to higher concentrations. Citrus fruit consumption was associated with higher vitamin C concentrations for both

Figure 1
Weighted cumulative distributions of vitamin C concentration, by smoking status, household population aged 20 to 79, Canada excluding territories, 2012/2013



Source: 2012/2013 Canadian Health Measures Survey.

Figure 2
Weighted cumulative distributions of vitamin C concentration, by body mass index, household population aged 20 to 79, Canada excluding territories, 2012/2013



Source: 2012/2013 Canadian Health Measures Survey.

smokers and non-smokers. Together, the factors in these models accounted for 27% of the variance in vitamin C concentrations among non-smokers, and 39% of the variance among smokers.

The models by BMI showed that citrus fruit consumption was positively associated with vitamin C concentrations among people who were overweight, and that both fruit juice and citrus fruit consumption were positively associated with concentrations among those who were obese (Table 2). Consumption of fruit juice and citrus fruit was not significantly associated with vitamin C concentrations among people who were neither overweight nor obese. Smoking status was not related to concentrations for any BMI subgroup. The factors in these models accounted for 30% of the variance in vitamin C concentrations among people who were neither overweight nor obese and among those who were overweight, and for 25% of the variance among those who were obese.

Based on the models by supplement use, among people who did not take vitamin C-containing supplements, smoking, obesity, and infrequent citrus fruit consumption were associated with relatively low concentrations. Among supplement users, those who were obese had lower concentrations than did people who were neither overweight nor obese. The factors in this analysis accounted for 21% of the variance in vitamin C concentrations among people who did not take vitamin C-containing supplements, and 16% of the variance among supplement users.

Discussion

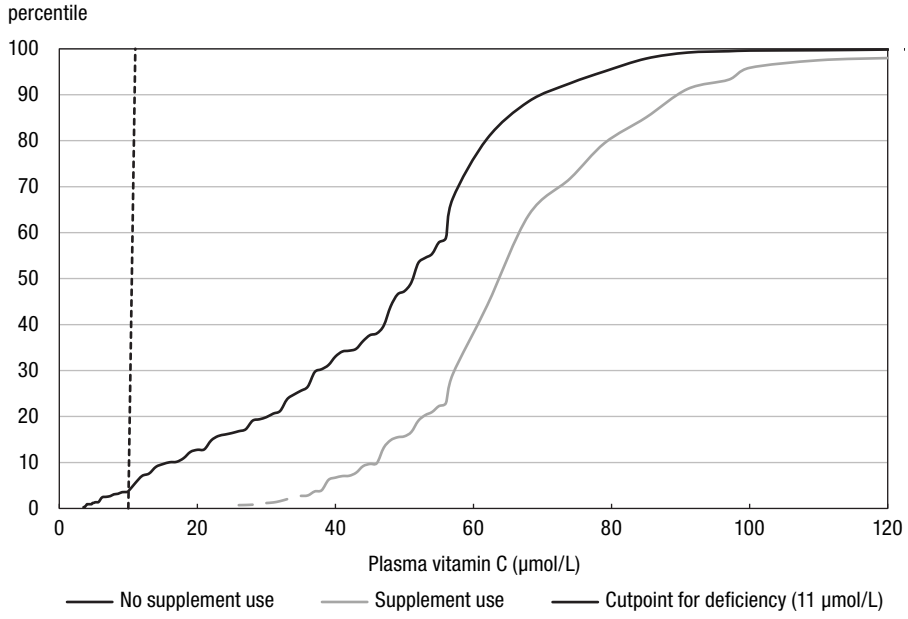
According to this analysis of data from the 2012/2013 CHMS, vitamin C concentrations were generally adequate among Canadian adults, even groups that tend to have lower concentrations (smokers, obese). Concentrations were related to smoking, obesity and supplement use in the adult population overall. Fruit juice

Table 2
Regression model estimates (beta, *p*-values) of associations of supplement use, smoking and body mass index with plasma vitamin C concentrations, by selected characteristics, household population aged 20 to 79, Canada excluding territories, 2012/2013

	Supplement use				Smoking				Body mass index					
	No supplement use		Supplement users		Smokers		Non-smokers		Neither overweight nor obese		Overweight		Obese	
	beta	*p*-value	beta	*p*-value	beta	*p*-value	beta	*p*-value	beta	*p*-value	beta	*p*-value	beta	*p*-value
R^2	R^2: 0.2084		R^2: 0.1563		R^2: 0.3865		R^2: 0.2731		R^2: 0.3036		R^2: 0.2912		R^2: 0.2517	
Intercept	67.69*	0.00	83.50*	0.00	70.26*	0.00	66.73*	0.00	67.45*	0.00	61.57*	0.00	60.40*	0.00
Sex														
Men	-8.38*	0.01	-7.27*	0.04	-16.87*	0.00	-6.12*	0.01	-14.41*	0.01	-3.06	0.27	-7.59*	0.03
Women†	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Age group														
20 to 39	-1.69	0.57	-6.28	0.27	3.26	0.65	-4.77	0.06	-5.32	0.18	-1.56	0.75	-3.32	0.37
40 to 59	-3.54	0.21	-0.06	0.98	-2.02	0.74	-3.49	0.11	-5.21	0.26	-1.34	0.65	-5.74	0.16
60 to 79†	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Education														
Less than college/university graduation	-5.56*	0.00	-2.96	0.41	-0.83	0.86	-6.43*	0.01	-8.58*	0.01	-3.71	0.27	-1.86	0.48
College/University graduation†	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Vitamin C-containing supplement use														
No†	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Yes	...	...	...	...	21.54*	0.00	16.28*	0.00	18.40*	0.01	17.89*	0.00	13.28*	0.00
Smoking														
Daily/Occasional	-7.32*	0.03	-1.88	0.78	...	...	...	...	-5.14	0.14	-7.42	0.06	-1.35	0.70
Non-smoker†	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Body mass index														
Neither overweight or obese†	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Overweight	-3.42	0.27	-6.55	0.31	-3.51	0.50	-5.01	0.05	...	...	...	...	...	...
Obese	-9.87*	0.00	-18.00*	0.01	-5.66	0.32	-13.76*	0.00	...	...	...	...	...	...
Fruit juice consumption														
Daily†	...	...	...	...	...	...	...	...	...	...	...	...	...	...
At least once a month	-1.22	0.56	-1.51	0.75	-9.80*	0.03	0.60	0.78	2.09	0.53	-3.00	0.32	-5.80	0.08
Less than once a month or never	-6.27	0.12	-0.89	0.90	-17.59*	0.03	-3.42	0.17	-3.31	0.41	-5.40	0.20	-11.52*	0.00
Citrus fruit consumption														
At least once a week†	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Less than once a week	-8.01*	0.00	-2.98	0.47	-14.06*	0.01	-4.82*	0.04	-0.87	0.75	-12.24*	0.00	-7.27*	0.02

... not applicable
* significantly different from reference category ($p < 0.05$)
† reference category
Note: All covariates were included in models.
Source: 2012/2013 Canadian Health Measures Survey.

Figure 3
Weighted cumulative distributions of vitamin C concentration, by supplement use, household population aged 20 to 79, Canada excluding territories, 2012/2013



Source: 2012/2013 Canadian Health Measures Survey.

What is already known on this subject?

- Vitamin C plays an important role in the body.
- Vitamin C requirements are higher in smokers.
- Canadians' vitamin C status has not been measured since 1970/1972.

What does this study add?

- The 2012/2013 Canadian Health Measures Survey provided direct (plasma) measures of vitamin C for a national sample of Canadians.
- Fewer than 3% of Canadian adults were vitamin C-deficient.
- Vitamin C concentrations were lower among smokers and obese individuals, and higher among people who took supplements and/or frequently consumed fruit juice or citrus fruit.

consumption was significant only for groups that tend to have low concentrations. The highest concentrations were among supplement users, women, people who consumed fruit juice or citrus fruit daily, and people who were neither overweight nor obese.

The last measurement of the vitamin C status of Canadians at the national level was the 1970/1972 Nutrition Canada Survey. Despite the potential for intra-laboratory and inter-assay variation,[8] the demographic factors associated with vitamin C status in 1970/1972 were similar to CHMS findings, with the highest median values among women aged 40 to 64, and the lowest among men aged 40 or older.

In the United States, according to results of the 2003/2004 National Health and Nutrition Examination Survey, adults aged 20 or older had a mean vitamin C concentration of 49 µmol/L, measured using isocratic reverse-phase HPLC method with electrochemical detection,[18] similar to the mean of 53 µmol/L in the present study. Slightly lower concentrations were reported in other research. A large cohort of non-smoking American adults had a mean concentration, measured spectrophotometrically, of 44 µmol/L.[19] A 2002 cross-sectional cohort study in Finland reported mean concentrations, measured by HPLC using electrochemical detection, of 37 µmol/L in men and 44 µmol/L in women.[20] Despite different assay methods, the results of these studies suggest that the vitamin C status of Canadians is comparable to that of other countries.

Consistent with direct measures in other analyses,[18,21-23] the CHMS found significantly lower vitamin C concentrations among smokers than non-smokers, although mean concentrations were adequate in both groups. The Institute of Medicine recommends that smokers consume vitamin C in higher amounts than non-smokers due to oxidative stress and increased metabolic turnover of vitamin C.[1] This is supported by the CHMS results showing that higher consumption of fruit juice and citrus fruit was associated with increased vitamin C concentrations among smokers, but not among non-smokers. Smokers and non-smokers were equally likely to take vitamin C-containing supplements.

As reported in other research,[19,24,25] vitamin C concentrations were lower among people who were obese. It is speculated that this may be due to differences in fat storage or metabolism between normal-weight and obese individuals.[19] In the present study, consumption of fruit juice and citrus fruit was significantly associated with higher vitamin C concentrations among obese people, even when other covariates were considered. This relationship was not found among people who were not obese.

Supplement use was strongly and consistently related to vitamin C concentrations. According to the 2012/2013 CHMS, 22% of Canadian adults took a vitamin C-containing supplement, which was lower than the 37% of American men and 47% of American women who reported taking such supplements in 2003/2004.[18] Further, the prevalence

of vitamin C deficiency was higher in the United States: 7.1% versus 2.9% in the present study. Both figures indicate reductions in the prevalence of deficiency over time in each country.[8,18]

Consumption of fruit juice and citrus fruit has been shown to contribute to higher vitamin C intake,[14] and in the present analysis, even when potential confounders were taken into account, was related to higher vitamin C concentrations for groups among whom concentrations tend to be low. However, many Canadians[26] do not consume the amounts of vegetables and fruit recommended in *Canada's Food Guide*.[27] The ability to examine dietary vitamin C intake in the CHMS was limited, and the usual frequency of consumption of vegetables and fruit could not be measured. Nonetheless, the positive association between the frequency of citrus fruit consumption and vitamin C concentrations indicates the contribution of this food group to overall vitamin C status. Additional research is needed on the role of dietary intake.

Limitations

The results of this analysis should be considered in the context of several limitations. The cut-off for vitamin C deficiency may exclude people with marginal deficiency, which is not consistently defined.[28-31]

Vitamin C data were collected only for a subsample; weighting ensured that the sample was representative of the target population, but the sample size was too small to allow further breakdowns (for example, deficiency) for some subgroups.

Logistical and cost constraints limited the number of CHMS collection sites to 16. Therefore, it was not possible to include all covariates in a single regression model; separate models were fitted for subgroups of interest, but consequently, direct comparisons of the magnitude of the regression coefficients could not be made.

Although the models were moderately strong (accounting for 16% to 39% of the variance in vitamin C concentrations), key explanatory variables may be missing. For example, fruit juice and citrus fruit consumption was based on a non-quantitative food frequency question and did not permit estimation of total dietary intake of vitamin C. Cycle 4 of the CHMS will collect vitamin C information; as those data become available, exploration of these and relationships may be possible.

Conclusion

Results of the 2012/2013 CHMS demonstrated that the vitamin C status of Canadians aged 20 to 79 was generally adequate, with fewer than 3% being deficient. Smoking and higher BMI contributed to lower plasma vitamin C concentrations; supplement use and consumption of fruit juice and citrus fruit contributed to higher concentrations. ■

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