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Health Reports

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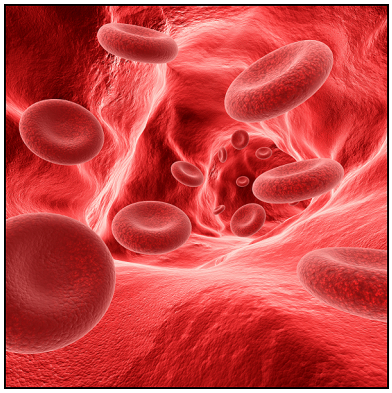
Iron sufficiency of Canadians



by Marcia Cooper, Linda Greene-Finestone, Hélène Lowell, Johanne Levesque and Stacey Robinson

November, 2012

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.	not available for any reference period
..	not available for a specific reference period
...	not applicable
0	true zero or a value rounded to zero
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 ($p < 0.05$)

Iron sufficiency of Canadians

by Marcia Cooper, Linda Greene-Finestone, Hélène Lowell, Johanne Levesque and Stacey Robinson

Released online November 21, 2012

Abstract

Background
Iron deficiency is the most common nutritional deficiency in the world, but little is known about the iron status of people in Canada, where the last estimates are from 1970-1972.

Data and methods
The data are from cycle 2 (2009 to 2011) of the Canadian Health Measures Survey, which collected blood samples from a nationally representative sample of Canadians aged 3 to 79. Descriptive statistics (percentages, arithmetic means, geometric means) were used to estimate hemoglobin and serum ferritin concentrations, and other markers of iron status. Analyses were performed by age/sex group, household income, self-perceived health, diet, and use of iron supplements. World Health Organization reference values (2001) were used to estimate the prevalence of iron sufficiency and anemia.

Results
The overall prevalence of anemia was low in the 2009-to-2011 period—97% of Canadians had sufficient hemoglobin levels. Generally, hemoglobin concentration increased compared with 1970-1972; however, at ages 65 to 79, rates of anemia were higher than in 1970-1972. Depleted iron stores were found in 13% of females aged 12 to 19 and 9% of females aged 20 to 49. Lower household income was associated with a lower prevalence of hemoglobin sufficiency, but was not related to lower serum ferritin sufficiency. Self-perceived health and diet were not significantly associated with hemoglobin and serum ferritin levels.

Interpretation
The lack of a relationship between iron status and diet may be attributable to the use of questions about food consumption frequency that were not specifically designed to estimate dietary iron intake. Factors other than iron intake might have contributed to the increase in the prevalence of anemia among seniors.

Keywords
Anemia, dietary supplements, ferritin, hemoglobin, nutritional status

Authors
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Iron is essential for biochemical functions in the body at every stage of life. The physiological manifestations of iron-deficiency anemia include reduced immune function and resistance to infection, impaired cognitive performance and behaviour, decreased thermoregulatory performance and energy metabolism, diminished exercise or work capacity, and increased incidence of preterm deliveries and low birthweight infants.[1,2] In developed countries, iron deficiency and iron-deficiency anemia may be caused by inadequate intake of dietary iron, consumption of poorly available forms of iron, or diminished iron absorption due to dietary inhibitors. Increased demands for iron because of growth, menstrual losses, or pregnancy may also be factors.[3]

Iron deficiency affects 20% to 25% of the world population,[4] with iron-deficiency anemia the most common type of anemia. In the United States, the prevalence of iron-deficiency anemia among youth and adults is estimated at 2% to 5% in females and 1% to 2% in males.[5] The last national estimates of the iron status of Canadians were based on the 1970-1972 Nutrition Canada Survey.[6] At that time, the overall prevalence of "high risk" of anemia (Hb< 100 g/L) was minimal (less than 1.5%) among women overall.[7] At ages 10 to 19, "high risk" of anemia was 0.4% among males and 0.0% among females.[7]

This study uses data from cycle 2 (2009 to 2011) of the Canadian Health Measures Survey (CHMS) to update estimates of the iron status of Canadians. These data allow for the examination of associations between selected socio-demographic and health variables and measures of iron status.

Stages of iron depletion

Body iron is found primarily in hemoglobin, the protein in red blood cells that carries oxygen to tissues.[8] The amount of iron stored in the body is directly related to the serum ferritin level (amount of ferritin in the blood). Iron deficiency is typically defined in three stages of increasing severity: iron storage depletion as indicated by low serum ferritin; mild iron deficiency without anemia, based on laboratory evidence of iron-deficient erythropoiesis; and overt iron-deficiency anemia.

Although serum ferritin is a valid measure of total iron storage,[9,10] as a sole indicator of iron deficiency, it must be interpreted cautiously; concentrations could increase as a result of infections and disorders such as chronic inflammation, malignancy and liver disease.[11] In developed countries, this usually occurs too infrequently at the population level to change the value of serum ferritin in nutrition surveys.[11]

During the second stage of iron deficiency, transport iron decreases. A reduction in the size of circulating red blood cells, measured as the mean corpuscular volume, is a reliable indication of reduced hemoglobin synthesis; low values can indicate iron-deficient erythropoiesis.[11]

The final stage—iron-deficiency anemia—is often characterized by a reduction in the blood concentration of hemoglobin.[8] Because micronutrient deficiencies (notably, vitamin B_{12}, folate and vitamin A) and infections that lead to inflammation are other (less frequent) causes of anemia,[12] hemoglobin concentration should be combined with other measures to establish iron deficiency as the cause of anemia.[13]

Methods

Data source

The CHMS covers the population aged 3 to 79. The cycle 2 sample represented approximately 96% of the population. Residents of Indian reserves and Crown lands, institutions and certain remote regions, and full-time members of the Canadian Forces were excluded. Data were collected at 18 sites across Canada from August 2009 through November 2011.[14] The survey consisted of a face-to-face household interview to obtain demographic, socio-economic, health, nutrition and lifestyle information, and a subsequent visit to a mobile examination centre for a series of direct physical measurements including collection of blood and urine samples.[14]

About three-quarters (75.9%) of the households selected for cycle 2 agreed to participate; 90.5% of them completed the household questionnaire, and 81.7% of those that completed the household questionnaire attended the mobile examination centre. The total sample was comprised of 6,395 respondents. The overall response rate was 55.5%.[14] Because two people were selected in some households, this rate is not the result of multiplying the household and person response rates. Survey weights produced for the CHMS were used to account for the different stages of non-response. Characteristics of the sample can be found in Appendix Table A.

Data for 1970-1972 from Nutrition Canada[7,15] were used as a reference to compare iron status prevalence estimates.

Blood collection

Blood was collected by venipuncture. A lavender-top EDTA vacutainer of whole blood specimen was collected for the complete blood count analysis. Blood was collected in SST-Red/Grey or Gold top vacutainers, and the serum was separated and processed for the ferritin analysis. The sample size for all hemoglobin, serum ferritin and mean corpuscular volume results was 6,008 respondents.

Standardized procedures and quality control monitoring were developed for the collection, processing, aliquoting and analysis of biospecimens and for shipping them to the testing laboratory.

Complete blood count analysis

Whole blood was analyzed for the complete blood count at the mobile examination centre laboratory using the Beckman Coulter HmX Hematology Analyzer. The laboratory participates in proficiency testing programs and has strict quality control procedures. The complete blood count analysis included determination of hemoglobin and of mean corpuscular volume.

Ferritin analysis

Serum aliquots were frozen at -20°C and shipped once a week on dry ice to the Health Canada Nutrition Laboratory. Serum was analysed for ferritin by solid phase, two-site chemiluminescent immunometric assay using the Immulite 2000 (Siemens HealthCare Diagnostics).

Internal quality control and standardized procedures were developed for every assay performed in this laboratory. The Health Canada Nutrition Laboratory participates in the College of American Pathologists Proficiency Testing Program.

Vitamin B_{12} and red blood cell folate analysis

Vitamin B_{12} and folate deficiency were investigated to determine if factors other than iron deficiency contributed to the prevalence of anemia. Serum vitamin B_{12} and red blood cell folate analyses were performed on the Immulite 2000.

Reference values

World Health Organization reference values by sex and age group[16] were used to estimate iron sufficiency (Appendix Table B). Hemoglobin concentration alone was used as a measure of anemia.[17] Serum ferritin concentration is commonly used as an indicator of iron deficiency because it reflects tissue stores.[9,10] Mean corpuscular volume was also used to determine if low hemoglobin concentrations were associated with iron deficiency. Measures above serum ferritin and hemoglobin reference values provided estimates of the prevalence of sufficient iron stores and/or the absence of anemia.

For the most part, the analysis, presents estimates of *sufficiency* (at or above reference values), because this measure yielded larger sample sizes,

resulting in a significant decrease in sampling variability, and thus, more reliable estimates than measures of *deficiency* (below the reference values). The reference values for vitamin B_{12} deficiency and red blood cell folate deficiency were: < 148 pmol/L[18] and < 320 nmol/L, respectively.[19]

Covariates

Age, sex, household income and self-perceived health were examined for associations with hemoglobin and serum ferritin levels. Six age groups were specified: 3 to 5, 6 to 11, 12 to 19, 20 to 49, 50 to 64, and 65 to 79 years. Household income during the past 12 months was based on the total income (before taxes and deductions) of all household members divided by the number of people in the household. Respondents reported total household income as a best estimate or within a range, the midpoint of which was used for calculations. These adjusted household income values were grouped into approximate quartiles.

Respondents' self-perceived health was categorized as excellent/very good/good or fair/poor.

Associations between diet and iron sufficiency status were determined based on responses to questions in the household interview about the frequency of consumption of: red meat (including beef, pork, lamb, liver and other organ meats), beef/pork hot dogs, and sausage or bacon; fortified non-heme iron sources (including hot/cold cereal, brown/white bread and pasta); and vegetables and fruit.

Respondents answered questions about medication use in the past month, including prescriptions, over-the-counter medications, and health products and herbal remedies. Reported medications were classified based on the Anatomical Therapeutic Chemical Classification System and the Defined Daily Dose.[20] Iron supplement users were categorized as: 1) those consuming only multivitamins containing 5 to 30 mg of ferrous iron (Fe2+) per defined daily dose (with corresponding limits for the various ferric iron (Fe3+) salts); and 2) those consuming iron preparations and all combination products containing more than 30 mg Fe2+ (or corresponding amounts of Fe3+ salts) per defined daily dose, with or without multivitamins.

Statistical analyses

All analyses used the CHMS survey weights generated by Statistics Canada to represent the Canadian population aged 3 to 79. Analyses were conducted in SAS[21] and SUDAAN[22] softwares (using DDF=13 in SUDAAN). Percentages, arithmetic means, geometric means for serum ferritin, and 95% confidence intervals were calculated. Student's t-test was used to test differences between percentages, arithmetic means, and geometric means. Statistical significance was determined at $p < 0.05$, but was Bonferroni-adjusted depending on the number of comparisons.[23]

Results

Hemoglobin

The mean hemoglobin concentration among Canadians aged 3 to 79 was 142 g/L. Concentrations were significantly higher among males than females (Table 1). For both sexes, hemoglobin values tended to be relatively low among the youngest and oldest age groups, with the lowest mean among children aged 3 to 5 (127 g/L). The mean concentration among males was highest at ages 20 to 49 (153 g/L). For females older than age 5, mean concentrations were relatively consistent across age groups (132 to 136 g/L), although women aged 50 to 64 had a significantly higher concentration than did girls aged 6 to 11.

For 97% of people aged 3 to 79, hemoglobin levels were at or above age group and sex reference values, indicating that they were not anemic. Hemoglobin sufficiency ranged from

Table 1
Mean hemoglobin, mean corpuscular volume, and ferritin concentrations, by age group and sex, household population aged 3 to 79, Canada, 2009 to 2011

Age group (years)/ Sex	Hemoglobin (g/L)			Mean corpuscular volume (fL)			Serum ferritin (µg/L)		
	Arithmetic mean	95% confidence interval		Arithmetic mean	95% confidence interval		Geometric mean	95% confidence interval	
		from	to		from	to		from	to
Total 3 to 79	142	141	143	90	90	91	81	79	84
Male	149*	148	150	90	90	91	128*	123	133
Female	134	133	135	90	90	91	52	48	55
Total 3 to 5	127	126	128	83	83	84	33	29	38
Males									
6 to 11	131	130	133	84	83	85	40	36	45
12 to 19	148*†	146	150	88†	87	89	58*†	53	64
20 to 49	153*†‡	151	154	91†	90	91	164*†	152	177
50 to 64	150*†‡	148	151	92†	91	93	166*†	148	187
65 to 79	147*†§	145	150	93†	92	94	155*†	138	175
Females									
6 to 11	132	130	134	85	83	87	42	38	45
12 to 19	134	132	136	89†	88	90	32†	28	36
20 to 49	135	134	136	91†‡	90	91	41†	38	44
50 to 64	136†	134	137	92†‡§	91	93	85†‡§	73	98
65 to 79	133	131	135	92†‡§	91	93	89†‡§	74	107

* significantly different from females ($p<0.05$)
† significantly different from ages 6 to 11 of same sex ($p<0.05$ adjusted for number of comparisons)
‡ significantly different from ages 12 to 19 of same sex ($p<0.05$ adjusted for number of comparisons)
§ significantly different from estimate for ages 20 to 49 of same sex ($p<0.05$ adjusted for number of comparisons)
Source: 2009 to 2011 Canadian Health Measures Survey.

a low of 90% among women aged 65 to 79 to nearly 100% for males aged 12 to 19. Hemoglobin sufficiency was significantly higher for males than females, a reflection of percentages close to 100% among males aged 12 to 19 and 20 to 49 (Table 2). In total, based on their hemoglobin concentration, 4% of females were anemic.

A comparison of 2009 to 2011 CHMS data with results of the 1970-1972 Nutrition Canada Survey, taking differences in age groups and hemoglobin reference values into account, suggests that at most ages, the percentage of people with hemoglobin concentrations above reference values has risen during the past 40 years (Table 2). The exception is the 65-to-79 age group, among whom the prevalence of hemoglobin sufficiency is now lower (90% for women; 93% for men) than in the early 1970s (94% for women; 96% for men).[15]

Serum ferritin

According to the 2009 to 2011 CHMS, the geometric mean serum ferritin concentration among Canadians was 81µg/L. Concentrations were significantly higher among males than females. The range among females was from 32 µg/L (ages 12 to 19) to 89 µg/L (ages 65 to 79), and among males, from 40 µg/L (ages 6 to 11) to 166 µg/L (ages 50 to 64) (Table 1).

Although 96% of Canadians had sufficient serum ferritin concentrations, the figure was significantly higher among males (99%) than females (92%). This difference reflected higher sufficiency for males than females at ages 12 to 19 (99% versus 87%) and 20 to 49 (99% versus 91%) (Table 3). The highest prevalence of *insufficient* serum ferritin was among females aged 12 to 19 (13%).

Anemia

Approximately 3% of Canadians had anemia (low hemoglobin). Anemia, however, can be caused not only by low iron, but by other factors.

Serum ferritin and mean corpuscular volume concentrations indicate if low hemoglobin is due to iron depletion—very low percentages of sufficiency in these measures would be expected if that was the case. Yet among low-hemoglobin individuals, 75% had mean corpuscular volume concentrations above reference values, and 62% had serum ferritin concentration or mean corpuscular volume above reference values (data not shown). If the low hemoglobin was primarily a result of low iron, these percentages would be drastically lower. This suggests that the anemia may not have been due to iron deficiency.

Overall, 85% of people with anemia had sufficient vitamin B_{12} levels. However, at ages 65 to 79, the ages at which anemia was most prevalent, vitamin B_{12} sufficiency was low (72%), particularly for women (59%).

Red blood cell folate levels were sufficient for all age/sex groups, and therefore, did not appear to be associated with anemia.

Income, health, diet, and supplement use

Mean hemoglobin concentrations were significantly lower among residents of households in the lowest income quartile, compared with those in the highest: 140 g/L versus 143 g/L (data not shown). Similarly, the prevalence of hemoglobin sufficiency was significantly lower among people in the lowest income quartile, compared with the highest. Mean serum ferritin concentrations did not differ significantly by household income quartile (data not shown).

People in good/very good/excellent health had significantly higher mean hemoglobin concentrations than did

Table 2
Prevalence of sufficient hemoglobin, by age group and sex, household population aged 3 to 79, Canada, 1970-1972 and 2009 to 2011

	Greater than or equal to reference value for age group			
	1970-1972†	2009 to 2011		
			95% confidence interval	
Age group (years)/ Sex	%	%	from	to
3 to 5	99.0	99.5	98.0	100.9
6 to 11				
Males	95.4	96.9	94.0	99.8
Females	95.4	97.1	94.3	100.0
12 to 19				
Males	98.6	99.8*	99.5	100.1
Females	96.1	96.8	95.1	98.5
20 to 49				
Males	98.7	99.1*	97.4	100.8
Females	94.4	96.3	94.8	97.9
50 to 64				
Males	96.5	98.9	97.9	99.9
Females	94.4	96.6	93.5	99.7
65 to 79				
Males	94.3	92.8	90.2	95.5
Females	96.0	89.9	84.0	95.8

* significantly different from females (p<0.05)
† Nutrition Canada age groups (years) are 0 to 4, 5 to 9, 10 to 19, 20 to 39, 40 to 64, and 65 or older
Source: 2009 to 2011 Canadian Health Measures Survey; 1970-1972 Nutrition Canada Survey.

Table 3
Prevalence of sufficient serum ferritin, by age group and sex, household population aged 3 to 79, Canada, 2009 to 2011

	Greater than or equal to reference value for age group		
		95% confidence interval	
Age group (years)/ Sex	%	from	to
3 to 5	96.8	95.0	98.6
6 to 11			
Males	97.6	95.0	100.2
Females	98.7	97.9	99.4
12 to 19			
Males	99.1*	98.3	99.8
Females	86.9	82.4	91.4
20 to 49			
Males	98.7*	97.5	99.9
Females	90.9	87.2	94.6
50 to 64			
Males	98.6	97.1	100.1
Females	94.3	89.4	99.2
65 to 79			
Males	99.9	99.6	100.1
Females	93.9	85.0	102.7

* significantly different from females (p<0.05)
Source: 2009 to 2011 Canadian Health Measures Survey.

Table 4
Prevalence of sufficient hemoglobin and serum ferritin, by use of iron supplements, age group and sex, household population aged 3 to 79, Canada, 2009 to 2011

Supplement use/ Age group (years)/ Sex	Greater than or equal to reference value for age group					
	Hemoglobin			Serum ferritin		
	%	95% confidence interval from	to	%	95% confidence interval from	to
No supplement use						
3 to 11	97.8	96.1	99.4	97.8	96.7	99.0
12 to 19						
Males	99.8	99.5	100.1	99.2	98.4	99.9
Females	96.6	94.5	98.7	88.0	83.5	92.5
20 to 79						
Males	98.3	96.9	99.6	99.1	98.5	99.7
Females	95.9	94.1	97.7	92.4	89.8	95.0
Multivitamins						
3 to 11	97.9	95.2	100.6	97.0	94.3	99.7
12 to 19						
Males	100.0	100.0	100.0	98.1	92.3	103.9
Females	98.0	93.0	103.1	87.7	73.1	102.2
20 to 79						
Males	98.6	96.7	100.5	96.9	92.2	101.5
Females	96.0	93.2	98.8	96.2	93.1	99.3
Iron preparations						
3 to 11	F	...	...	F	...	...
12 to 19						
Males	F	...	...	F	...	...
Females	96.4	83.5	109.3	60.4[E]	17.5	103.3
20 to 79						
Males	86.5	65.7	107.3	F	...	...
Females	88.7	80.8	96.6	81.8	63.0	100.5

... not applicable
[E] use with caution
F too unreliable to be published
Note: The iron preparations group includes 20 respondents who also took multivitamins.
Source: 2009 to 2011 Canadian Health Measures Survey.

those who rated their health fair/poor (data not shown). Mean serum ferritin concentrations and the prevalence of hemoglobin and serum ferritin sufficiency did not differ significantly by self-perceived health (data not shown).

No association emerged between mean hemoglobin or serum ferritin concentrations and the consumption of red meat, grains, and fruit and vegetables (data not shown).

An estimated 13% of Canadians aged 3 to 79 took iron-containing multivitamins, and 2% took iron preparations (containing a therapeutic dose) with or without multivitamins. No significant differences in hemoglobin and serum ferritin sufficiency were apparent between those who took iron-containing multivitamins, compared with those who reported no iron supplementation (Table 4). However, adults aged 20 to 79 taking iron preparations had a lower hemoglobin concentration (130 g/L) than did those not taking supplements (144 g/L) and those taking multivitamins only (143 g/L) (data not shown). Similarly, the mean serum ferritin concentration of adults consuming iron preparations was significantly lower (41 μg/L) than that of adults not consuming supplements (100 μg/L) (data not shown).

Discussion

Based on data from the 2009 to 2011 CHMS, the majority of Canadians are not anemic—90% to 100% of individuals in each age/sex group had hemoglobin concentrations considered sufficient. As well, 93% had both hemoglobin and serum ferritin levels above reference values, suggesting that iron-deficiency anemia was not widespread.

However, at ages 12 to 19, only 85% of females had both hemoglobin and serum ferritin sufficiency, indicating a higher risk of iron-deficiency anemia; 13% had serum ferritin levels below the reference values. These results are consistent with four small-scale Canadian studies that documented similar or higher percentages of adolescents (male and female) with low serum ferritin.[24-27]

Although this analysis focused on iron *sufficiency*, it is possible to report some estimates of iron *deficiency*. Around 5% of Canadians 3 to 79 (8% of females) had low serum ferritin concentrations, suggesting low iron stores.

The comparison with 1970-1972 Nutrition Canada data suggests that the prevalence of anemia is currently lower in all age groups younger than 65. But among seniors, the prevalence of anemia is now higher, particularly for women. Even so, nearly 80% had either sufficient mean corpuscular volume (normally sized red blood cells) or sufficient serum ferritin levels. Therefore, the apparent increase in the prevalence of anemia at ages 65 to 79 may be attributable to factors other than iron deficiency. For example, vitamin B_{12} deficiency is a cause of pernicious anemia, with an average age at diagnosis of 60.[28] Nonetheless, according to the 2009 to 2011 CHMS, approximately three-quarters of 65- to 79-year-olds with anemia were sufficient in vitamin B_{12}. Red blood cell folate did not appear to contribute to anemia. As well, blood lead levels are low among Canadians.[29]

What is already known on this subject?

- Iron deficiency is associated with health risks, such as reduced immune function and diminished exercise or work capacity.
- Although iron deficiency is common in the world population, the 1970-1972 Nutrition Canada Survey reported a low risk of iron-deficient anemia among Canadians.
- More recent smaller-scale studies have indicated some Canadian subgroups are at a greater risk of low iron status.

What does this study add?

- The prevalence of anemia remains low in the Canadian population overall.
- Compared with 40 years ago, higher rates of anemia were found among seniors.
- Self-perceived health and selected dietary items were not significantly associated with hemoglobin and serum ferritin levels.

Socio-economic status may influence determinants of iron status. For instance, higher-income households could have greater access to iron-rich foods.[24] Based on the CHMS results, residents of households in the lowest income quartile had a lower mean concentration of hemoglobin and a lower prevalence of hemoglobin sufficiency than did people in the highest income quartile. However, this pattern did not persist when serum ferritin was used as a measure of iron stores.

Self-perceived health was not associated with hemoglobin or serum ferritin sufficiency. However, mean hemoglobin was higher among people who reported that they were in good/very good/excellent health. This is consistent with other research findings for young women with depleted iron stores,[30,31] though in contrast to those with anemia.[31]

Although diet is related to iron status, no relationship was found with red meat, grain, or fruit and vegetable consumption. However, CHMS data on dietary iron intake were limited. The questionnaire assessed the frequency, not the amount, of consumption of a partial list of dietary sources of iron. Hence, the variables may not have been specific enough to estimate iron intake and its dietary inhibitors and enhancers. Additionally, information about meat did not include the full scope of meat consumption, thereby potentially underestimating heme iron intake. A recent study[32] found a weak association between red meat consumption and iron status. As well, other evidence indicates adequate dietary iron intake by much of the population. In the 2004 Canadian Community Health Survey—Nutrition, the prevalence of inadequate dietary intake of iron was generally low (less than 3%) for most age/sex groups; the exception was females aged 14 to 50 (12% to 18%).[33]

Use of iron-containing multivitamins was not related to hemoglobin and serum ferritin levels or their adequacy. This may reflect insufficient absorption of the non-heme iron (5 mg to 30 mg per tablet) in the supplement as a result of iron inhibitors such as calcium in the diet. Furthermore, absorption of iron from multivitamins may be reduced in iron-replete individuals.[34] People taking higher, therapeutic doses of iron (ferrous fumarate, ferrous sulphate, ferrous gluconate) appeared to be a different group, as evidenced by their lower hemoglobin and serum ferritin levels. These findings should be interpreted cautiously, as no information was collected about dosage, frequency of use, timing of intake, or reason for taking high-dose supplements.

Limitations

A number of limitations are associated with this analysis.

The CHMS excluded infants and Aboriginal people living on reserves. Furthermore, because this is a national sample, regional differences cannot be determinated.

Using hemoglobin alone to identify iron deficiency anemia tends to yield overestimates, because anemia due to other causes is included.[8] However, this study attempted to account for some of these causes, such as vitamin B_{12} and red blood cell folate deficiency.

The CHMS did not include other iron indices such as soluble transferrin receptor, which could have been helpful in distinguishing iron-deficiency anemia from all-cause anemia.[35]

Conclusion

For the first time since the early 1970s, iron indices were measured for the Canadian population. The prevalence of anemia was generally low, although depleted iron stores were detected in 9% of women aged 20 to 49, and 13% of females aged 12 to 19. While this study found higher rates of anemia among seniors, factors other than iron deficiency may have contributed to this result. ■

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Appendix

Table A
Percentage distribution of sample with valid whole blood hemoglobin, mean corpuscular volume and serum ferritin concentrations, by sex, age group, household income and self-perceived health, household population aged 3 to 79, Canada, 2009 to 2011

Sex/Age group/ Household income quartile/ Self-perceived health	Number	%	95% confidence interval from	to
Total	6,008	**100.0**	…	…
Sex				
Males	2,911	50.2	49.9	50.4
Females	3,097	49.8	49.6	50.1
Age group (years)				
3 to 5	487	2.8	2.6	3.1
6 to 11	950	6.2	5.9	6.5
12 to 19	991	10.2	9.9	10.4
20 to 49	2,042	47.2	45.5	48.9
50 to 64	874	22.8	20.8	25.0
65 to 79	664	10.8	10.0	11.6
Household income quartile (past 12 months)				
1 (lowest)	1,556	27.1	22.8	31.9
2	1,539	22.5	19.4	25.8
3	1,470	24.7	21.8	27.8
4 (highest)	1,443	25.7	21.2	30.9
Self-perceived health				
Excellent	1,502	16.9	15.5	18.4
Very good	2,273	38.2	35.6	40.9
Good	1,759	35.0	31.6	38.5
Fair	382	7.5	6.3	8.9
Poor	92	2.5[E]	1.6	3.6

... not applicable
[E] use with caution
Source: 2009 to 2011 Canadian Health Measures Survey.

Table B
World Health Organization hemoglobin, mean corpuscular volume and ferritin reference values for sufficiency, based on criteria, 2001

Age group (years)/ Sex	Hemoglobin (g/L)	Mean corpuscular volume (fL)	Serum ferritin (µg/L)
3 to 5	≥110	...	≥12
3 to 4	...	≥73	...
4	...	≥74	...
6 to 11	≥115	...	≥15
6 to 7	...	≥74	...
8 to 11	...	≥76	...
12 to 19	≥120	...	≥15
Females			
12 to 14	...	≥77	...
15 to 17	...	≥78	...
18 to 19	...	≥81	...
Males			
12 to 14	...	≥77	...
15 to 17	...	≥79	...
18 to 19	...	≥80	...
20 to 49	...	≥81	≥15
Non-pregnant women	≥120	...	...
Pregnant women	≥110	...	...
Men	≥130	≥80	...
50 to 79		...	...
Non-pregnant women	≥120	≥80	≥15
Men	≥130	...	...

... not applicable
Source: World Health Organization (WHO)/UNICEF/UNU. *Iron Deficiency Anaemia: Assessment, Prevention, and Control. A Guide for Programme Managers.* Geneva: World Health Organization, 2001.