The Iron Status of Canadian Adolescents and Adults: Current Knowledge and Practical Implications

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Abstract

Overview: Iron is an essential nutrient, playing a central role in oxygen transport and cellular energy metabolism. The importance of ensuring adequate bioavailable dietary iron stems from the severe consequences associated with iron deficiency (ID) and anemia, including reduced immune function and resistance to infection, developmental delays and irreversible cognitive deficits in young children, impaired physical work performance, and adverse pregnancy outcomes.

Specific populations: Poor dietary iron intake and ID exist in Canada, particularly in women of reproductive age. Data from the provincial nutrition surveys suggest that the prevalence of inadequate iron intakes (and low intakes of absorbable iron) among women under 50 years of age is over 10%, which may reflect poor iron status. Teenage girls are at risk for low iron stores because of the adolescent growth spurt and the onset of menstruation; those who are vegetarian are at even greater risk.

Conclusions: The Canadian diet has changed so that grain products are now the main source of dietary iron for all age groups. The public must be educated to ensure the consumption of adequate quantities of bioavailable iron and enhancing factors such as vitamin C. Industry, government, and health professionals must work together to promote healthy eating patterns and the selection of appropriate foods.

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Résumé

Aperçu. Le fer est un nutriment essentiel qui joue un rôle primordial dans le transport de l'oxygène et le métabolisme énergétique de la cellule. Assurer un apport suffisant en fer alimentaire biodisponible est important, car des conséquences graves sont associées à la carence en fer (CF) et à l'anémie : diminution de la fonction immunitaire et de la résistance à l'infection, retards de développement et déficits intellectuels irréversibles chez le jeune enfant, altération de la capacité d'effort physique et effets néfastes sur l'issue de la grossesse.

Populations visées. Au Canada, on constate des apports faibles en fer alimentaire et des CF, en particulier chez les femmes en âge de procréer. Les données des enquêtes nutritionnelles provinciales révèlent que la prévalence des apports insuffisants en fer (et de faibles apports en fer absorbable) chez les femmes de moins de 50 ans se chiffre à plus de 10 %, ce qui peut refléter un état en fer inadéquat. Les adolescentes sont à risque de faibles réserves en fer en raison de la poussée de croissance et du début des menstruations; chez les végétariennes, le risque est encore plus élevé.

Conclusions. Dans l'alimentation des Canadiens, les produits céréaliers sont désormais la principale source alimentaire de fer dans tous les groupes d'âge. On doit informer la population de consommer suffisamment de fer biodisponible et de facteurs favorisants, telle la vitamine C. Industrie, gouvernement et professionnels de la santé doivent s'unir pour promouvoir des modèles d'alimentation saine et un choix d'aliments appropriés.

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OVERVIEW

Definitions of iron deficiency and anemia

Iron is an essential nutrient for all individuals at every stage of life. Iron deficiency (ID) is believed to affect 20% to 50% of the world's population, which means it is the most common nutritional deficiency in the world (1). It is particularly prevalent in developing countries. However, recent data suggest that approximately 5% of toddlers and 12% of premenopausal women in the United States have ID (abnormal values for at least two of serum ferritin [SF], transferrin saturation [TS], and free erythrocyte protoporphyrin [FEP]); approximately 4% of women have iron deficiency anemia (IDA) (iron deficiency and a low hemoglobin [Hb] value) (2). Similarly, despite the abundance of iron-containing foods available in Canada, distinct population groups have, or are at risk for, ID and IDA.

Physiological manifestations of anemia

Because iron plays several key roles in oxygen transport and utilization, iron depletion may impair many important biological functions. The physiological manifestations of IDA 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 birth-weight infants (3,4). Iron deficiency and IDA may be caused by an inadequate intake of dietary iron, consumption of poorly available forms of iron, or decreased iron absorption due to dietary inhibitors; it also may result from increased demands for iron because of growth, menstrual losses, or pregnancy.

Iron status and absorption

Iron status is determined by three primary factors: intake, stores, and excretion. The balance between iron requirements and the amount of iron absorbed is controlled by dietary factors (i.e., the amount, type, and bioavailability of iron in the diet) and physiological processes (i.e., a person's iron status, and, consequently her or his capacity to absorb the ingested iron) (5).

Absorption depends not only on the person's iron status, but also on dietary factors that enhance absorption (e.g., ascorbic acid, meat, fish, poultry) or inhibit absorption (e.g., polyphenols in tea, coffee, and cocoa; phytate in cereal bran, legumes, and nuts; oxalates in spinach and chard). Dietary iron is mainly in the non-heme form, the absorption of which is highly influenced by other dietary components. Heme iron, primarily from the hemoglobin and myoglobin of meat, poultry, and fish, is absorbed better than non-heme iron, and is affected much less by other dietary constituents (6). Although the estimation of an individual's total dietary iron intake is important, the amount of bioavailable dietary iron (i.e., the amount that the body can absorb and use) is a better predictor of a person's iron status (7).

Stages of iron depletion

Iron depletion is a gradual sequence of events, usually described in terms of three stages of increasing severity. The first stage is ID or depletion onset, during which liver and bone marrow iron stores are depleted. (Routinely this is diagnosed by a low SF of <12 μg/L) (8). Depletion progresses through impairment of erythropoiesis (reduced TS and elevated FEP and serum transferrin receptor), and the third and final stage is IDA (low Hb, low hematocrit, low mean cell volume, low mean cell Hb concentration [MCHC], and/or low red blood cell count).

Diagnosing anemia

The presence of infection or inflammation may complicate the interpretation of SF values (9). Hemoglobin concentration alone does not distinguish between IDA and anemia from other causes, although many research papers report IDA diagnosed on the basis of a single biochemical measure (10). To diagnose IDA, Hb levels must be combined with ferritin levels or other biochemical measures to help prevent misdiagnosis (11,12).

Intake recommendations and evaluation

New recommendations for iron and other nutrients have recently been established (13). The Dietary Reference Intakes (DRIs) expand and replace the existing Recommended Dietary Allowances (RDAs) for Americans (14) and the Recommended Nutrient Intakes (RNIs) for Canadians (15). The DRIs refer to four nutrient-based reference values: Estimated Average Requirements (EARs), RDAs, Adequate Intakes, and Tolerable Upper Intake Levels. The EAR has been suggested as a useful standard for evaluating the prevalence of inadequate nutrient intakes in population groups (13,16).

For iron, the probability approach has been applied to estimate the proportion of individuals at risk for inadequate intakes (17). With the probability approach, the risk of inadequacy associated with each intake level in the distribution is computed and the results are averaged across the entire group to obtain a prevalence estimate. This allows a number of uncertainty factors to be included in the estimation (e.g., the fraction of oral contraceptive users) (17).

Compared with values in the 1990 Nutrition Recommendations for Canadians (15), the RDAs for iron are higher for most people, especially infants, adolescents, women, and vegetarians. These higher levels are a result of changes in the methodology used to estimate the requirement distribution, and of a greater understanding of the pattern of individual variability within the population (18).

> Iron depletion is a gradual sequence of events.

The publication of the DRIs provides a strong rationale for re-examining Canadians' dietary iron intakes and the prevalence of ID and IDA. Several investigators have examined Canadians' iron status and intakes, with specific emphasis on vulnerable populations such as adolescents, women, and vegetarians. Numerous other studies have shown that ID and IDA are present in Canadian infants and children (19). Provincial and national surveys in Canada provide important information on iron intakes.

Depending on the year of publication, study results of dietary intakes are reported as a comparison of populations' mean intakes with both the 1990 Canadian RNIs and the 1989 US RDAs, or as an estimate of the prevalence of inadequacy, using the methodology of the DRI report (13). Tables 1 and 2 outline the findings of these studies.

SPECIFIC POPULATIONS

Adolescents

Growth periods of childhood and adolescence increase the demand for absorbed iron (20). Rapid skeletal muscle development, together with expanding blood volume, accidental blood losses, and menses, create demands for absorbed iron of 0.93 to 1.93 mg/day and 0.85 to 1.85 mg/day in adolescent boys and girls, respectively (13).

Typically, this increase in iron needs is at least partially met through enhanced appetite, particularly in males (21). Iron status may be compromised because of poor food choices and lifestyle behaviours that limit intakes of nutritious iron-containing foods. According to the DRIs, the RDA for iron for 14- to 18-year-olds is 11 mg/day for males and 15 mg/day for females (13).

For children and adolescents aged ten to 19 years, the prevalence of frank anemia was low for males (0.4%) and females (0.1%) in the Nutrition Canada Survey (22). The percentages of this age group considered at moderate risk were 5.4% and 2.6% for males and females, respectively. Three subsequent Canadian studies have documented a high proportion of adolescents with iron status indicators below normal levels (25% to 39% with depleted iron stores) (23-25). A recent study conducted in 395 healthy adolescents showed an ID prevalence of 6% (SF <12 g/L and/or TS <16%) and an IDA prevalence of 3.4% (SF <12 g/L and TS <16% and Hb <120 g/L) in females (26). These reports are consistent with US IDA prevalence rates of 2% to 4% in healthy adolescents (two of three abnormal values [SF, TS, or FEP] plus abnormal Hb) (2). Low iron stores or anemia was found in a group of 58 pregnant adolescents during the third trimester (78% with plasma ferritin [PF] <12 µg/L and 22% with Hb <110 g/L) (27). Iron deficiency was observed in 47% of pregnant adolescents in another study (28).

In the early 1970s, male adolescents' iron intakes were adequate in Canada, whereas females' median intakes were marginal and close to inadequacy (22). Seoane et al. determined that iron intakes were below the RNI for 67% of ten- to 18-year-olds (24). Recent studies have shown sufficient intakes of dietary iron among healthy adolescent males and females (25,26). In the Food Habits of Canadians study, mean iron intakes exceeded the RNI for adolescent males and females (aged 13 to 17 years) (29), even though almost 60% of female teens had only the minimum recommended number of servings of meat and alternatives (30). On the other hand, the mean of six servings of grain products per day was within the recommendations. Although mean iron intakes exceeded the RNI, possibly absorbable iron requirements were not met, particularly as the number of meat and alternatives servings was below the minimum recommended amount.

Taken together, these studies indicate recent reductions in the proportion of adolescents with ID, and higher dietary iron intakes for adolescents. These improvements must, however, be examined with caution as they may be explained by changes in the diagnostic criteria used to define ID and IDA. These criteria include shifts from reliance on a single indicator to the use of multiple indicators.

Adults

As with measurements in other subgroups in Canada, measurements of adults' iron status and intakes are scarce. No national studies of iron status have been completed since the Nutrition Canada survey. However, a number of smaller studies have been completed to assess the prevalence of poor iron status (Table 1). Not all of these studies have used the same cut-off values for categorizing iron status,

Table 1
Summary of Canadian studies/reports examining the iron status of Canadian adolescents and adults[1]

Study	Gender/ dietary habits	Age (years)	n	Criteria for ID/IDA	Prevalence
Nutrition Canada Survey, 1973 (National) (22)	F and M	>20	6,767	High risk for IDA: Hb <120 g/L (M) Hb <100 g/L (F) MCHC <30%	High risk for IDA: 1.3% with Hb <120 g/L (M) 1.5% with MCHC <30% (M) (20 to 65 years old) 1.9% with Hb <100 g/L (F) 7.7% with MCHC <30% (F) (20 to 65 years old)
Anderson et al., 1981 (Guelph, Ontario area) (56)	F, V	52.9 ± 15.3	56	High risk for IDA: Hb <100 g/L TS <16% saturation Moderate risk: Hb – 100 to 120 g/L TS – 16% to 20% saturation Low risk: Hb >120 g/L TS >20% saturation	High risk for IDA: 0 with Hb <100 g/L 6% with TS <16% Moderate risk: 22% with Hb 100 to 120 g/L 6% with TS 16% to 20% Low risk: 78% with Hb >120 g/L 86% with TS >20%
Seoane et al., 1985 (Quebec) (24)	F and M	10 to 18	574	SF <12 mcg/L (ID) Hb <120 g/L (M - 10 to 12) (IDA) Hb < 120 g/L (F - 10 to 18) (IDA) Hb <130 g/L (M - 13 to 18) (IDA)	39% (ID) (most age 13 to 15 years) 4%[2] (IDA)
Bindra and Gibson, 1986 (Guelph, Kitchener-Waterloo, Ontario) (57)	F and M, LOV	37.7 ± 10.5 (M) 33.3 ± 7.4 (F)	59 (M) 55 (F)	SF <12 mcg/L (ID) TS <16% (ID) MCHC <32% (ID) (2 of 3 values abnormal) 2 of 3 values abnormal plus Hb <140 g/L (M) (IDA) Hb <120 g/L (F) (IDA)	5% (M) (ID) 33% (F) (ID) 5% (M) (IDA) 16% (F) (IDA)

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Table 1 continued…

Study	Gender/ dietary habits	Age (years)	n	Criteria for ID/IDA	Prevalence
Godel et al., 1992 (Western Canadian Arctic) (36)	F (pregnant)	N/A	121	PF <15 mcg/L (ID)	34% (1st and 2nd trimesters) (ID) 25% (at delivery) (ID) 52% (postnatally) (ID)
Turgeon-O'Brien et al., 1994 (Quebec) (28)	F (pregnant)	16.7 ± 1.3 28.0 ± 3.1	38 68	SF <12 mcg/L TS <16% Hb <110 g/L (2 of 3 values abnormal: ID)	47% (ID) – adolescents 66% (ID) – adults
Gadowsky et al., 1995 (Ontario) (27)	F (pregnant)	17.0 ± 0.2	58	PF <12 mcg/L (ID) Hb <110 g/L (IDA)	78% - last trimester (ID) 22% – last trimester (IDA)
Donovan and Gibson, 1995 (Ontario) (58)	F, LOV, SV, OM	14 to 19	124	PF <12 mcg/L (ID) Hb <117 g/L (IDA)	29% - LOV (ID) 44% - SV (ID) 17% - OM (ID) 2.5% - LOV (IDA) 0% - SV (IDA) 3.5% - OM (IDA)
Turgeon-O'Brien et al., 2000 (Quebec) (35)	F (pregnant)	29.5 ± 4.8	202	SF <20 mcg/L (IDep) Hb <110 g/L (IDA) Hb <105 g/L (IDA - 2nd trimester)	35% at 16 ± 4 weeks (IDep) 6% (1st trimester) (IDA) 3% (2nd trimester) (IDA) 24% (3rd trimester) (IDA)
Rioux and Michaud, 2001 (New Brunswick) (38)	F (pregnant)	N/A	952	Hb <110 g/L (IDA)	21.4% - 3rd trimester (Moncton) 11.5% - 3rd trimester (Peninsula) 52% - postnatally (Moncton) 40% - postnatally (Peninsula)
Deegan et al., 2005 (Edmonton, Alberta) (26)	F and M	16.0 ± 0.8	164 (M) 232 (F)	SF <12 mcg/L TS <16% Hb <130 g/L (M) Hb <120 g/L (F) (2 of 3 values abnormal for ID and all for IDA)	6% (F) (ID) 0% (M) (ID) 3.4% (F) (IDA) 0% (M) (IDA)

[1]Iron depletion, iron deficiency, and iron deficiency anemia have been defined by the authors. For example, some authors may have used only a single indicator, such as Hb level, to classify IDA.

[2]The authors note that the classification was tentative; it was based on Hb level as the sole determinant.

F = female
g/L = grams per litre
Hb = hemoglobin
Hct = hematocrit
ID = iron deficiency
IDA = iron deficiency anemia
IDep = iron depletion
LOV = lacto-ovo-vegetarian
M = male
mcg/L = micrograms per litre
MCHC = mean corpuscular hemoglobin concentration
n = number
n/a = not available
OM = omnivore
PF = plasma ferritin
SF = serum ferritin
SV = semi-vegetarian
TS = transferrin saturation
V = vegetarian

which may influence prevalence estimates of ID and IDA across decades and from different regions.

Women: Menstruation, pregnancy, and lactation influence women's iron requirements (31). Heavy blood loss (>80 mL/month) occurs during menstruation in approximately 10% of women and can lead to IDA if insufficient dietary iron is consumed.

Iron deficiency anemia is the most common nutritional deficiency during pregnancy (9), particularly during the third trimester. This is because of the increased demands for iron to supply the growing fetus and the placenta, and to sustain the biological changes associated with pregnancy (15,31). In late pregnancy, a woman's iron needs may increase to five times her pre-pregnancy requirement. These needs may not be met with food alone, even if it is fortified, and increased iron absorption can provide only partial physiological compensation (32). The current RDA for iron in pregnant women is higher than in non-pregnant women of the same age (27 mg vs. 18 mg) (13).

Potential adverse pregnancy outcomes with inadequate iron intake include preterm delivery, low birth weight, and

Table 2
Summary of Canadian studies/reports examining the iron intakes of Canadian adolescents and adults[1]

Study	Gender/ dietary habits	Age (years)	n	Assessment instruments	Proportion meeting recommendations
Gibson et al., 1984 (Guelph, Ontario) (40)	F	30.3 ± 6.1 (PreM) 67.5 ± 6.6 (PostM)	100 96	3-day dietary record	73% of PreM women < recommended estimate for absorbed iron (1.12 mg/day) 30% of PostM women < recommended estimate for absorbed iron (0.67 mg/day)
Seoane et al., 1985 (Quebec) (24)	F	10 to 18	574	3-day dietary record	34% with low dietary iron intakes (F - 10 to 12 years) (<10 mg/day) 80% with low dietary iron intakes (F – 13 to 15 and 16 to 18 years) (<13 and <14 mg/day, respectively)
Payette and Gray-Donald, 1991 (Quebec) (64)	F and M	65 to 89	35 (M) 47 (F)	7-day food record	Mean iron intakes for men (14.1 ± 4.1 mg) and women (11.2 ± 3.4 mg) > recommendations (M - 9 mg/day and F - 8 mg/day)
Janelle and Barr, 1995 (British Columbia) (59)	F, LOV, VEG, OM	20 to 40	45	3-day dietary record	Mean iron intakes for OM (15.3 ± 4.9 mg) and VEG. (17.7 ± 3.8 mg) >RDA of 15 mg/day; LOV consumed 92% of RDA
Donovan and Gibson, 1995 (Guelph, Ontario) (58)	F, LOV, SV, OM	14 to 19	124	Weighed food record	66% LOV, 10% SV, and 24% OM had available iron intakes < mean estimated average requirement (1.4 to 1.7 mg/day)
Doran and Evers, 1997 (Ontario) (50)	F (postpartum)	15 to 41	183	24-hour recall	Mean iron intakes <RDA (13 vs. 15 mg/day) (Ontario, low SES) for women > poverty line Mean iron intakes <RDA (12 vs. 15 mg) for women < poverty line
Tarasuk and Beaton, 1999 (Ontario; families receiving food assistance) (51)	F	33 ± 7.0	145	24-hour recall	38.2% of women with usual iron intakes < their requirement
Barr and Broughton, 2000 (British Columbia) (60)	F	31.9 ± 8.8	193	24-hour recall	No statistically significant differences in iron intakes between vegetarians (16.2 ± 6.8 mg) and nonvegetarians (15.3 ± 7.5 mg)
Gray-Donald et al., 2000 (Quebec) (29)	F and M	13 to 17 18 to 65	178 (teenagers) 1,544 (adults)	24-hour recall	Mean iron intakes for women (13.5 mg) aged 18 to 49 approximated RNI (13 mg/day) Mean iron intake levels for adolescent females (15.1 mg) and males (22.2 mg) > recommendations (RNI: M - 10 mg, F – 12 to 13 mg/day)
Tessier et al., 2002 (Quebec) (48)	F and M	18 to 74	1,036 (M) 1,082 (F)	24-hour recall	2.5% <EAR total iron (M) (EAR: 6 to 7.7 mg) 18.9% <EAR total iron (F) (EAR: 5 to 8.1 mg) 25.6% <EAR absorbed iron (M) (EAR: 1.08 to 1.4 mg) 66.2% <EAR absorbed iron (F) (EAR: 0.88 to 1.45 mg)

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Table 2 continued…

Study	Gender/ dietary habits	Age (years)	n	Assessment instruments	Proportion meeting recommendations
Dewolfe and Millan, 2003 (Kingston, Ontario) (63)	F and M	74.2 (65 to 95)	105	24-hour recall	Mean iron intakes (11.4 mg) >RDA for both men and women (8 mg/day)
Deegan et al., 2004 (Alberta) (26)	F and M	16 ± 0.8	164 (M) 232 (F)	114-item FFQ	Mean iron intakes (22.1 ± 10.5 mg) >RDA for both males and females (11 to 15 mg/day)
Surveys					
Nutrition Canada, 1973 (National) (22)	F and M	>20	6,767	24-hour recall	Inadequate iron intakes in 3.8%, 3.5%, and 4.9% of men aged 20 to 39, 40 to 64, and >65, respectively Inadequate iron intakes in 37.7%, 30.7%, and 8.4% of women aged 20 to 39, 40 to 64, and >65, respectively
Nova Scotia Nutrition Survey, 1993 (Nova Scotia) (42)	F and M	18 to 74	2,118: 1,036 (M) 1,082 (F)	24-hour recall FFQ	Mean iron intakes >RNI for all men and for women >50 Mean intakes for women (10.7 mg) 18 to 49 < RNI
Quebec Nutrition Survey, 1995 (Quebec) (43)	F and M	18 to 74	2,212: 1,069 (M) 1,143 (F)	24-hour recall FFQ	Mean iron intakes >RNI for all men and for women >50 Mean intakes for women (11.8 mg) aged 18 to 49 <RNI (13 mg/day)
Saskatchewan Nutrition Survey, 2001 (Saskatchewan) (44)	F and M	18 to 74	1,264: 579 (M) 685 (F)	24-hour recall FFQ	60% to 70% of women aged 18 to 34 and 35 to 49 had intakes <RNI (13 mg/day). Most men had intakes >RNI
Prince Edward Island Nutrition Survey, 2002 (Prince Edward Island) (46)	F and M	18 to 74	1,995: 995 (M) 1,000 (F)	24-hour recall FFQ	Mean iron intakes >RDA for all men and for women >50 Mean intakes for women (10.8 mg) aged 18 to 49 <RDA (18 mg/day) Prevalence of inadequate iron intakes among women <50 was 29%; prevalence was very low for all other age/sex groups
Ontario Food Survey, 2003 (Ontario) (17)	F and M	18 to 74	1,250: 480 (M) 770 (F)	24-hour recall FFQ	Mean iron intake >RDA for all men and for women >50 Mean intakes for women (13.5 mg) aged 18 to 49 < RDA (18 mg/day) Prevalence of inadequate iron intakes among women <50 was approximately 12%; prevalence was negligible for all other age/sex groups
British Columbia Nutrition Survey, 2004 (British Columbia) (47)	F and M	18 to 84	1,823: 868 (M) 955 (F)	24-hour recall FFQ	Mean iron intake >RDA for all men and for women >50 Mean intakes for women (13.1 mg) aged 18 to 49 <RDA (18 mg/day). Prevalence of inadequate iron intakes among women was 11.7% and 15.6% for ages 19 to 30 and 31 to 49, respectively; prevalence was very low for all other age/sex groups

[1]Depending on the year of publication, study results of dietary intakes are reported as a comparison of populations' mean intakes with both the 1990 Canadian RNIs and the 1989 US RDAs, or as an estimate of the prevalence of inadequacy, using the methodology of the DRI report (13).

EAR = Estimated Average Requirement
F = Female
FFQ = food frequency questionnaire
LOV = lacto-ovo-vegetarian
M = male
mg = milligram
OM = omnivore
PostM = postmenopausal
PreM = premenopausal
RDA = Recommended Daily Allowance
RNI = Recommended Nutrient Intake
SES = socioeconomic status
SV = semi-vegetarian
VEG = vegan

increased perinatal mortality (33,34). Shorter gestation was found in women with low SF levels (<20 μg/L) (279 +/-1 d) than in women with intermediate levels (20 μg/L to 50 μg/L) (283 +/-1 d) (35).

In the Nutrition Canada Survey, low iron stores were found in 8% to 10% of females under age 65, and the prevalence of those in the high-risk category (Hb <100 g/L) was minimal (<1.5%) (15). Fifty-nine percent of pregnant women had depleted iron stores, and 1% had IDA.

Valberg et al. (23) observed reduced iron stores in approximately 30% of menstruating women, and in 60% of pregnant women. Iron depletion (SF <20 μg/L) was present in 35% of women during the first trimester, while IDA (Hb <105 g/L with a low SF level of <12 μg/L) affected 6.2%, 3.2%, and 24.2% of subjects during the first, second, and third trimesters, respectively (35). Iron deficiency was found in 34% of Northwest Territories women in the first and second trimesters (36). Another study of pregnant women and infants in Nunavik (northern Quebec) showed that by term, 40% and 24% of pregnant women had Hb values below 115 g/L and 110 g/L, respectively, when IDA was defined solely on the basis of Hb values (37). In a retrospective analysis of obstetric records from greater Moncton, New Brunswick, 21% of women were defined as having IDA in the third trimester (38).

21% of women were defined as having IDA in the third trimester.

The Scientific Review Committee for the Canadian Nutrition Recommendations (15) and the US Institute of Medicine (IOM) (39) have recognized that many women have iron stores that are insufficient to meet pregnancy needs. The committee and the IOM therefore have advised that all pregnant women take a daily low-dose iron supplement (30 mg) during the second and third trimesters (39).

While intakes below recommended levels are not synonymous with deficiency, they clearly indicate increased risk of deficiency. Using the model of Monsen et al., Gibson et al. (40) observed that 73% of premenopausal women had intakes below the estimated requirement for absorbed iron (1.12 mg/day) (41). Canadian and provincial survey data on women of childbearing age have indicated average dietary intakes below the RNI (29,42-45). The prevalence of inadequate dietary iron intakes ranged from 12% to 29% for women younger than 50 (17,46,47). A comparison of mean iron intakes from the Food Habits of Canadians survey and the Nutrition Canada Survey showed that absolute iron intakes have increased for 20- to 64-year-old women (29). Despite this, the proportion of women with intakes below the EAR for absorbed iron was 66.2% (48). The prevalence of inadequacy was reassessed with the more appropriate probability approach, and was almost identical for absorbable iron and about 55% higher for total iron (49). For women below the poverty line, mean or usual intakes have been reported to be below requirements (50,51).

In Ontario, the contribution to iron intake by food category was 49% for grain products, 15% for meat, fish, and poultry, and 13% for vegetables and potatoes (17). These proportions are similar to those in other provincial surveys (42,44,47). Mandatory fortification of grain products with iron was legislated in 1976, and accounts for much of the increase in non-heme consumption. In addition, the contribution of total energy intake from animal products has declined from 22% to 14% in the past 30 years (17).

Men: Healthy men usually get enough iron from the food they eat. After age 19 years, when linear growth is complete, men generally need to replace only obligatory losses from the feces, skin, sweat, and urine (52). Provincial survey data suggest that the prevalence of inadequate dietary iron intakes was minimal for men (17,46,47).

SPECIAL POPULATIONS

Vegetarians: Iron absorption and iron status may be compromised in vegetarians because diets high in plant products also contain dietary iron inhibitors, such as phytates and polyphenols (52). Recommended iron intakes for vegetarians are 1.8 times those of nonvegetarians because of the lower bioavailability of iron from a vegetarian diet (13). (However, in research conducted in Sweden and Australia, the incidence of IDA has been similar among vegetarians and nonvegetarians (53-55).)

Iron status and intakes have been examined in both adolescent and adult vegetarian groups. Twenty-two percent of long-term vegetarian women were shown to be at moderate risk of ID (Hb of 100 to 120 g/L) (56). In a study of primarily lacto-ovo-vegetarian East Indian adults, the prevalence of ID (two of three values abnormal for SF, MCHC, or TS) was 5% for males and 33% for females. Iron deficiency anemia was found in 5% of males and 16% of females (two of three values abnormal plus abnormal Hb) (57). In a second study of females aged 14 to 19 years, 17% of omnivores had low iron stores (PF <12 μg/L), compared with 29% of lacto-ovo-vegetarians and 44% of semi-vegetarians (58).

Janelle and Barr (59) studied 22 nonvegetarian women who ate red meat three or more times a week, and 23 vegetarian women who had excluded all flesh foods from their diet for at least two years. Similarly, Barr and Broughton (60) assessed intakes in a broader cross-section of 68 nonvegetarian and 90 vegetarian women. Findings from these two studies were similar, in that iron intakes were above the recommendations for vegetarian women. However, iron bioavailability was not evaluated, and low bioavailability likely contributes to the prevalence of ID and IDA among vegetarians.

The elderly: Iron deficiency in the elderly has a number of possible causes. Among the most important factors are inadequate dietary iron consumption, increased iron loss primarily due to bleeding in the gastrointestinal tract, and low bioavailability of iron in the diet (61). Moreover, iron status may be compromised because of normal physiological changes with aging, along with the relatively high frequency of malnutrition and chronic disease among the elderly (62).

In a study of relatively healthy older adults, women had, on average, fewer than the recommended servings from all food groups, although this did not appear to reflect an inability to meet iron requirements (63). In the Nutrition Canada Survey, 42% of women aged 65 to 74 had iron intakes below requirements, but the prevalence of IDA (Hb <100 g/L) was very low. Mean iron intakes for men and women have been observed to be greater than the recommended 8 mg/day for older adults (17,46,47,63,64).

RELEVANCE TO PRACTICE

Adequacy of dietary iron depends not only on total intake, but also on the proportions of heme and non-heme iron, which have greatly differing bioavailability (65). Estimation of absorbable dietary iron may provide a more realistic idea of whether iron requirements are being met. With the present trend to decreased meat consumption and the corresponding increase in grain consumption in the overall population, high-risk groups may need to be targeted for education. The strategies should include one or both of the following: meat, fish, or poultry consumption in line with the standards of *Canada's Food Guide to Healthy Eating* (66), to improve bioavailable heme iron intake, and consumption of vitamin C-rich foods, which can increase absorption of non-heme iron when they are part of a meal.

In the summer of 2006, Statistics Canada released the results of Canadian Community Health Survey (CCHS) Cycle 2.2 on nutrition, which provides up-to-date information at the provincial level on nutrient intakes of the Canadian population, including iron intake data. Through the Canadian Health Measures Survey (CHMS), scheduled to take place in 2007-2008, there is the potential for assessing biochemical indicators of iron status using blood collected for various analyses. Both of these initiatives will provide much-needed information about Canadians' iron status. In the interim, continued work involving industry, government, and health professionals is needed to ensure education about, and appropriate access to, iron-rich foods.

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