Dietary intake and iron status of Australian vegetarian women[1,2]

Madeleine J Ball and Melinda A Bartlett

ABSTRACT

Background: Despite the possible overall health benefits of a vegetarian diet, there is concern that some vegetarians and infrequent meat eaters, particularly females, may have inadequate iron status because of low or no heme-iron intakes.

Objective: The objective was to investigate the nutritional intake and iron status of vegetarian women.

Design: The nutritional intakes of 50 free-living vegetarian women aged 18–45 y and 24 age-matched omnivorous control women were assessed by using 12-d weighed dietary records. Iron status was assessed by measuring hemoglobin and serum ferritin concentrations.

Results: There was no significant difference between mean (±SD) daily iron intakes of vegetarians and omnivores (10.7 ± 4.4 and 9.9 ± 2.9 mg, respectively), although heme-iron intakes were low in the vegetarians. Vegetarians had significantly lower intakes of protein ($P < 0.01$), saturated fat ($P < 0.01$), and cholesterol ($P < 0.001$), and significantly higher intakes of dietary fiber ($P < 0.001$) and vitamin C ($P < 0.05$). Mean serum ferritin concentrations were significantly lower ($P = 0.025$) in vegetarians (25.0 ± 16.2 μg/L) than in omnivores (45.5 ± 42.5 μg/L). However, similar numbers of vegetarians (18%) and omnivores (13%) had serum ferritin concentrations <12 μg/L, which is a value often used as an indicator of low iron stores. Hemoglobin concentrations were not significantly different.

Conclusion: It is important that both vegetarian and omnivorous women maintain an adequate iron status and follow dietary practices that enhance iron absorption. *Am J Clin Nutr* 1999;70:353–8.

KEY WORDS Iron status, ferritin, vegetarians, women, Australian recommended dietary intake, RDI, Australia

INTRODUCTION

Vegetarian diets have become increasingly popular in many countries in recent years, for health, philosophical, ecologic, and religious reasons. In the 1995 National Nutrition Survey (1), 6.2% of women aged 19–24 y and 5.2% aged 25–44 y reported that they were vegetarian. It is maintained that a well-balanced vegetarian diet is compatible with a healthy nutritional status (2–4). Furthermore, vegetarian lifestyles and dietary practices are associated with a lower incidence of some diseases, such as obesity, ischemic heart disease, gallstones, type 2 diabetes, and colon cancer. However, there is concern that some vegetarians and infrequent meat eaters, particularly females, may have an inadequate iron status because they have a low or no intake of heme iron (5). Heme iron from animal products is well absorbed at 15–35% of intake. Although nonheme-iron absorption is increased when body iron stores are low and by the concomitant ingestion of vitamin C (6) and meat proteins (7), absorption remains at only 2–20% of intake (8). Furthermore, absorption of nonheme iron may be inhibited by certain dietary constituents that are abundant in some vegetarian diets, such as tannins in tea and coffee (9), phytates in cereals and legumes (10), and possibly soy protein (11).

Several studies in different countries have shown vegetarians to have iron intakes that are higher than (12–16) or similar to (17–21) those of omnivores. However, only 2 of these studies—1 in New Zealand (12) and 1 in the United States (13)—have collected the 12-d dietary records needed to provide good estimates of the average actual intakes of iron (22). Few studies have given detailed assessments of the dietary sources of iron, and iron fortification of food varies in different countries.

A significantly lower serum ferritin concentration in vegetarians than in omnivores was reported in several studies (15, 18, 21); some found vegetarians to have inadequate serum ferritin concentrations (defined as <12 μg/L) compared with omnivores, despite adequate iron intakes (5, 12, 17). In other studies in which there were no apparent differences in iron status between vegetarians and omnivores, biochemical indexes such as hemoglobin, serum iron, and total-iron-binding capacity were measured but not serum ferritin (19, 23), or a significant proportion of the vegetarians had been taking iron supplements (20, 23). In the New Zealand study (12) of 31 female and 14 male vegetarians, 38% had low serum ferritin concentrations (<12 μg/L), but a similar proportion of vegetarian and omnivorous women had low serum ferritin concentrations. In New Zealand in 1992, there was no fortification of foods with iron. In Australia, some foods are now fortified with iron: breakfast cereals, breads, flours, pasta, meat, vegetable and yeast extracts, and textured vegetable protein (24). Despite this, population surveys indicate that significant numbers of Australian women have iron intakes below the Australian recommended dietary intake (RDI) for menstruating females (1, 25).

[1] From the School of Nutrition and Public Health, Deakin University, Burwood, Australia.

[2] Reprints not available. Address correspondence to MJ Ball, School of Health Sciences, Deakin University, 221 Burwood Highway, Burwood Victoria 3215 Australia. E-mail: mjbkr@deakin.edu.au.

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The RDI is 12–16 mg/d, with 12 mg/d generally considered to be acceptable (26). In the 1995 National Nutrition Survey (1), the mean iron intake of 19–24-y-old women was 11.9 mg/d and that of 25–44-y-old women was 12 mg/d. These data were derived from food-frequency questionnaires and 24-h dietary recalls.

The aim of the present study was to compare iron intakes and the iron status of Australian women who eat no red meat, or eat it less than once per month, with those of age-matched omnivorous women who eat meat regularly. Data from 12-d dietary records and serum ferritin measurements were used in the assessment.

SUBJECTS AND METHODS

Subjects

Fifty female vegetarians and vegans aged 18–45 y were recruited in Victoria, Australia, via posters and newspaper notices. For the purposes of this study, a vegetarian was defined as an individual who consumed red meat no more than once a month, consumed chicken or fish no more than once a week, and had been following this diet for ≥6 mo. Women who were pregnant or postmenopausal were excluded.

The vegetarian subjects were asked to recruit a female friend of the same age who ate red meat regularly to act as an omnivorous control subject; 13 did. The other 11 omnivorous control subjects were recruited via advertisement and matched with 11 vegetarians according to age and lifestyle on the basis of information provided in the questionnaires. All subjects gave written, informed consent for participation in the study, which was approved by the Ethics Committee of Deakin University.

Questionnaire and food diary

All subjects completed a questionnaire requesting details about age, occupation, exercise and smoking habits, blood donation, nutritional supplement use, the type of diet consumed, the length of time they had been following the diet, reasons motivating their choice of diet, and whether they had received dietary advice. Subjects were asked to complete 12-d weighed dietary records (excluding supplement use) after being given detailed instructions on how to complete them. A set of electronic scales was provided to each subject. When it was not possible to weigh food, subjects were told to describe the quantities consumed by using either household measures or photographs of representative portion sizes of common foods provided in the back of the dietary record. Subjects were given 1 mo in which to complete the 12-d dietary record, which included 3–4 weekend days. This dietary method was validated against weighed 7-d food records (27). Food and beverage intakes recorded on the 12 d by each participant were then entered into the dietary analysis program DIET-3 (Zyris, Queensland, Australia), data for which were obtained from Australian food-composition tables, with some additional foods added.

Hematologic measurements

A fasting venous blood sample was taken for the measurement of hemoglobin concentrations, hematocrit, and serum ferritin concentrations. Hemoglobin was measured immediately on a specimen collected into EDTA-containing tubes by using an electronic counter (HemoCue AB, Angelholm, Sweden). Hematocrit was measured by centrifuging a heparin-containing capillary tube at 2000 × *g* for 5 min at room temperature and comparing the height of the column of packed cells with the height of the entire column of red blood cells and plasma. The remainder of the blood sample was collected into an evacuated tube containing no anticoagulant, stored for 60 min, and then spun at 16 000 × *g* for 15 min at 4°C. The serum was separated and stored at −20°C. Serum ferritin was analyzed by a 2-site chemiluminometric immunoassay by using the Ciba Corning Automated Chemiluminescence System (Australian Diagnostics Corporation Pty Ltd, Ciba Corning Diagnostics Corp, Scoresby, Australia).

Statistical analysis

All statistical analyses were performed by using SPSS software (version 6.0; SPSS Inc, Chicago). A Mann-Whitney *U* test was performed to determine differences in nutrient intakes and biochemical measurements between vegetarians and omnivores because most measures were not normally distributed. Chi-square tests were performed to determine significant differences in numbers of subjects above or below cutoff points for nutrient intakes and biochemical values (27). Spearman's rank-order correlation coefficients were used to assess relations between dietary variables, anthropometric measures, and serum ferritin concentrations. Results are given as means ± SDs.

RESULTS

Subject characteristics

The 48 lactoovovegetarians, 2 vegans, and 24 omnivorous control subjects completed the study. The number of vegans was too small to warrant separate analysis; therefore, their data were combined with the data from the other vegetarian subjects. The vegetarians and vegans had been following this dietary practice for a mean of 5.2 y (range: 1–17 y). The mean (±SD) ages of the vegetarian and omnivorous groups were 25.3 ± 6.4 and 25.2 ± 6.2 y, respectively. Vegetarians had a body mass index (BMI; in kg/m^2) of 22.5 ± 3.8 and omnivores had a BMI of 22.4 ± 2.5. These values were not significantly different. Most vegetarian and omnivorous subjects were students (62.5% and 60.0%, respectively) and the remainder were employed full-time, except for one vegetarian subject who was unemployed.

All subjects reported that they were in good health. There was no significant difference in the prevalence of regular cigarette smoking between the omnivores and vegetarians (8% and 16%, respectively). Similarly, there was little difference in reported physical activity levels or menstrual regularity between the 2 groups. Significantly more omnivores (21%) than vegetarians (8%) donated blood regularly.

Nutrient intakes

Comparisons of daily intakes of macronutrients plus dietary fiber, iron, and vitamin C between vegetarians (n = 50) and omnivores (n = 24) are shown in **Table 1**. Mean daily nutrient intakes of the 24 vegetarians and their matched control subjects were also determined. When these data were compared with those of the vegetarian group as a whole, it was found that the 2 groups had very similar nutrient intakes and were also well-matched for age and BMI; thus, all comparisons were made by using the total vegetarian group.

The results indicated that vegetarians had significantly higher intakes of dietary fiber and vitamin C, but significantly lower intakes of protein, saturated fat, and cholesterol than did omnivores. Mean intakes of energy, total fat, total carbohydrate, and

TABLE 1
Daily dietary intakes of vegetarians and omnivores[1]

Nutrient	Omnivore (n = 24)	Vegetarian (n = 50)
Energy		
(MJ)	6.9 ± 1.4	6.9 ± 1.9
(kcal)	1655 ± 323	1652 ± 461
Protein		
(g)	66.7 ± 16.3	54.1 ± 14.7[2]
(% of total energy)	17.5	14.1
Fat		
(g)	65.0 ± 16.9	60.2 ± 21.8
(% of total energy)	37.2	34.1
Saturated fat		
(g)	28.2 ± 8.1	23.0 ± 9.1[2]
(% of total energy)	17.6	14.2
Polyunsaturated fat		
(g)	9.21 ± 3.1	11.5 ± 6.3
(% of total energy)	5.8	7.1
Carbohydrate		
(g)	183.3 ± 42.0	211.4 ± 59.5
(% of total energy)	45.3	51.8
Dietary fiber (g)	17.3 ± 4.9	24.4 ± 8.5[3]
Cholesterol (mg)	217.7 ± 62.6	122.5 ± 65.1[3]
Iron (mg)	9.9 ± 2.9	10.7 ± 4.4
Vitamin C (mg)	111.1 ± 85.3	149.9 ± 77.1[2]

[1] $\bar{x}$ ± SD.
[2,3] Significantly different from omnivores (Mann-Whitney U test): [2] $P \leq 0.01$, [3] $P \leq 0.001$.

iron were not significantly different between the 2 groups. The percentages of subjects who had iron intakes <50% of the RDI (<6 mg/d), below the RDI (<12 mg/d), and above the RDI (>12 mg/d) are shown in **Table 2**. Mean iron intakes of both the omnivores and vegetarians (9.9 and 10.7 mg/d, respectively) were below the Australian RDI for iron: 75% of the omnivores and 62% of the vegetarians had iron intakes below the RDI, and 4% of the omnivores and 10% of the vegetarians had intakes <50% of the RDI, but these differences were not significant.

Dietary sources of iron

Dietary sources of iron in vegetarians and omnivores are shown in **Figure 1**. In omnivores, ≈80% of all dietary iron was from cereals and cereal products (27.7%), meat and meat products (16.1%), vegetables (16.0%), breakfast cereals (15.0%), and nonalcoholic beverages (4.6%). In vegetarians, ≈80% of all dietary iron was from cereals and cereal products (29.8%), vegetables (27.1%), breakfast cereals (15.0%), and fruit (6.4%).

Biochemical measures

Hemoglobin concentrations and hematocrit values for both vegetarians and omnivores were within the normal reference range and were not significantly different between the 2 groups. Hemoglobin concentrations were 130 ± 8 g/L in the vegetarians and 134 ± 8 g/L in the omnivores and hematocrit values were 0.39 ± 0.05 and 0.39 ± 0.02, respectively. Serum ferritin concentrations of the vegetarians and omnivores are shown in **Table 3** and the distribution of serum ferritin in the 2 groups is shown in **Figure 2**. Serum ferritin concentrations were significantly lower in vegetarians than in omnivores. However, the percentages of vegetarians and omnivores with serum ferritin concentrations below both the reference range and the recommended cutoff point for indication of low iron stores (12 μg/L) were not significantly different (Table 3). Serum ferritin concentrations tended to be distributed toward the lower end of the reference range in vegetarians but toward the higher end in omnivores (Figure 2).

There was no significant correlation between serum ferritin values and iron intakes for the group as a whole (r = 0.08, P = 0.49) or when the 2 groups were analyzed separately: vegetarians (r = −0.02, P = 0.90) and omnivores (r = 0.29, P = 0.16). Mean daily meat intakes of omnivores did not correlate significantly with serum ferritin concentrations (r = 0.03, P = 0.88). Finally, there was no significant correlation between vitamin C intakes and serum ferritin concentrations in either vegetarians (r = 0.06, P = 0.66) or omnivores (r = 0.31, P = 0.14) or when the 2 groups were combined (r = 0.05, P = 0.67).

Dietary supplement use

Supplemental iron was not considered in the dietary analyses because it is difficult to estimate absorption from oral iron supplements. Although 7 (14%) vegetarians took iron supplements regularly (defined as >3 times/wk), no omnivores took iron supplements regularly. The most commonly used supplement was 80 mg ferrous sulfate 3–5 times/wk, and 2 subjects took a preparation containing 15 mg ferrous phosphate. When data for these 7 vegetarian subjects were excluded, the mean serum ferritin concentration of vegetarians was 24.2 ± 16.9 μg/L, which was not significantly different from that of the whole group. Similar numbers of omnivores (8%) and vegetarians (8%) took iron supplements occasionally (<2 times/wk). Supplement users had a wide range of serum ferritin values (11–46 μg/L) and addition of this supplemental intake to the dietary intake did not affect the lack of relation between iron intakes and serum ferritin concentrations.

DISCUSSION

Subject selection

Seventy-four women aged 18–45 y participated in this study. Women were chosen as the study group because they are at greater risk of developing iron deficiency than are men (28). Postmenopausal and adolescent females were excluded because they have a different prevalence of iron deficiency than do menstruating adults.

Age-matched (within 2 y) omnivorous friends of vegetarians were recruited as control subjects for >50% of the vegetarian subjects. This method of matching control subjects was used by

TABLE 2
Percentages of vegetarians and omnivores with iron intakes <50% of the RDI (<6 mg/d), less than the RDI (<12 mg/d), and greater than the RDI (>12 mg/d)[1]

Iron intake	Omnivores (n = 24)	Vegetarians (n = 50)
	%	
<6 mg/d	4	10
<12 mg/d	75	62
>12 mg/d	25	38

[1] Australian recommended dietary intake (RDI; 26) for iron for menstruating females is 12 mg/d. There were no significant differences between omnivores and vegetarians by chi-square test.

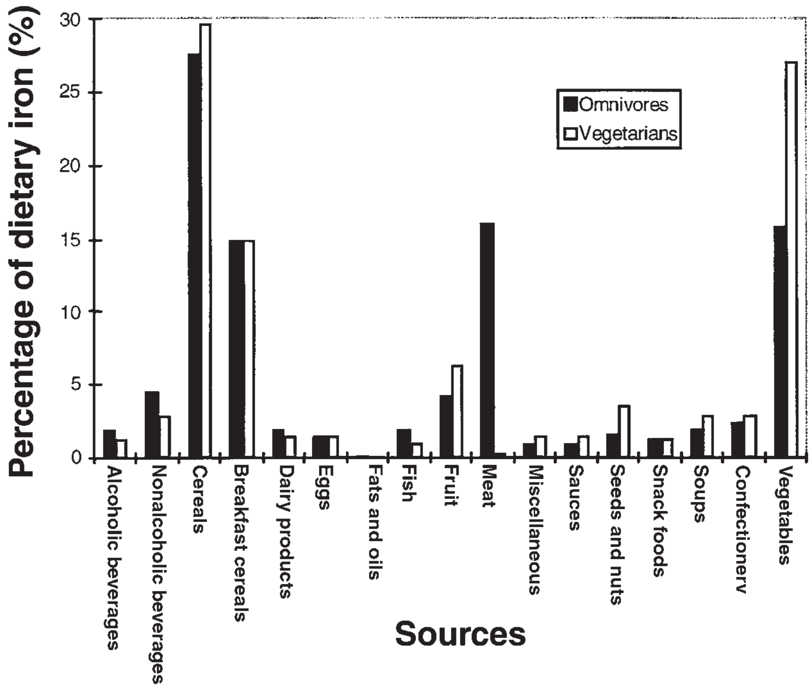

FIGURE 1. Dietary sources of iron in vegetarians and omnivores.

Thorogood et al (29) in a large study of vegetarians. It was anticipated that the vegetarians and their omnivorous friends would have similar lifestyle characteristics. Results showed that the vegetarians and omnivores were well-matched for age, BMI, general health, and occupation. The subjects in this study resembled those of Locong (20), being mainly young adult university students.

Nutrient intakes

A particularly important feature of this study was the use of a dietary record for a period of sufficient length to obtain reliable data on iron intakes. Twelve days is considered the shortest time in which iron intake can be assessed to within 10% of the average actual intake for individuals or groups when estimated weights are used (22).

Mean iron intakes were not significantly different between vegetarians (10.7 mg/d) and omnivores (9.9 mg/d), although vegetarians tended to have slightly higher intakes; median intakes were 9.4 and 8.9 mg/d, respectively. Several other studies also showed no significant differences in iron intake between vegetarians and omnivores (17–21). However, studies using dietary methods similar to those used in the present study found vegetarians to have significantly higher iron intakes than omnivores, with mean intakes of 16.8 and 14.6 mg/d (12) and 12.3 and 10.7 mg/d, respectively (13). The mean iron intake of both groups was below the Australian RDI for females (12–16 mg/d). Two other studies found female vegetarians and omnivores to have low iron intakes (15, 18). Vegetarians and omnivores consumed, on average, 89% and 83% of the RDI, respectively. Given the substantial safety factors incorporated into the RDIs, this finding does not necessarily suggest that most females are not consuming adequate iron but that further assessment is warranted; 75% of omnivores and 62% of vegetarians had intakes below the RDI and 10% of the vegetarians and 4% of the omnivores had intakes $<50\%$ of the RDI (<6 mg/d), although the differences between the 2 groups were not significant.

Intake of vitamin C, an enhancing factor for nonheme-iron absorption, was significantly higher in vegetarians than in omnivores, as was found in some other studies (17, 18). The fact that vegetarians tended to have lower iron stores probably reflects the interplay of other dietary factors.

Comparison of the dietary sources of iron showed, as expected, that vegetarians acquired more iron from vegetables, seeds and nuts, and fruit, and less from meat and meat products than did omnivores. Almost all of the iron consumed by the vegetarians was nonheme iron, whereas the ratio of iron from heme sources to that of nonheme sources in omnivores was 1:12.4, considering that half of the iron in meat is heme iron. Therefore, although vegetarians had slightly higher iron intakes, the iron was probably less bioavailable. In both vegetarians and omnivores, a significant proportion (15%) of iron was acquired from breakfast cereals. This value was greater than that found in the New Zealand study (12), in which breakfast cereals contributed only 8% and 6% of iron intake in vegetarians and omnivores,

TABLE 3
Serum ferritin concentrations of omnivores and vegetarians

	Omnivores (n = 24)	Vegetarians (n = 50)
	μg/L	
Serum ferritin (μg/L)	45.5 ± 42.5 (4–206)[1]	25.0 ± 16.2[2] (4–89)
Serum ferritin <12 μg/L (%)	12.5	18.0

[1] $\bar{x}$ ± SD; range in parentheses.
[2] Significantly different from omnivores, $P < 0.025$ (Mann-Whitney U test).

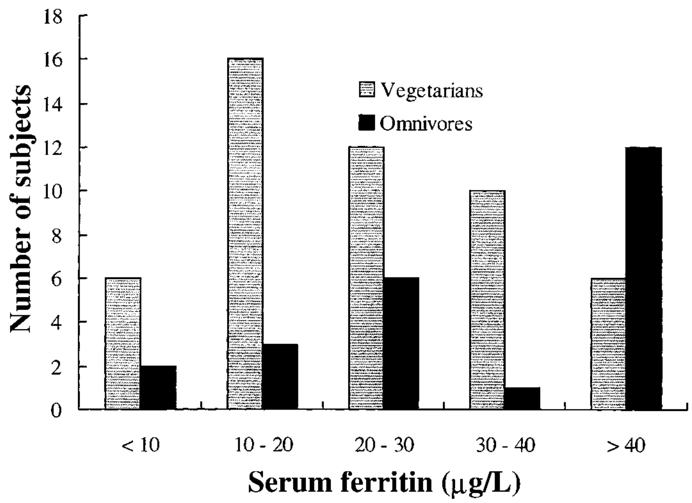

FIGURE 2. Distribution of serum ferritin concentrations in vegetarian and omnivorous women.

respectively, probably because these products are often fortified with iron in Australia but were not in New Zealand in 1992.

Lower intakes of protein, saturated fatty acids, and cholesterol in vegetarians than in omnivores were also found in several other studies (12, 16, 20), as were higher intakes of dietary fiber in vegetarians than in omnivores (12, 13, 16, 17, 20). Overall, the vegetarians had nutrient intakes closer to those recommended for healthy eating than did the omnivores.

Serum ferritin

Mean serum ferritin concentrations were significantly lower in vegetarians than in omnivores. This result agrees with the findings of several previous studies (5, 12, 17, 21). Of particular interest was the finding that the vegetarians did not have significantly more subjects with serum ferritin values below the recommended cutoff point for indication of low iron stores (12 μg/L) or below the reference range of the laboratory in which the samples were analyzed (10–219 μg/L) than did omnivores. This finding agrees with that of the New Zealand study (12). Because the women were not anemic, it is unlikely that their low ferritin concentrations were associated with specific symptoms, but low stores do indicate the risk of becoming anemic and symptomatic at times of increased stress or when there is excessive blood loss. However, high ferritin concentrations may also be unhealthy. Salonen (30) found a higher risk of myocardial infarction in those with serum ferritin concentrations >200 μg/L and the risk related to ferritin may be increased in those with elevated cholesterol. Vegetarians tend to have lower serum cholesterol and ferritin concentrations, and this could potentially provide some benefit with respect to cardiovascular disease risk. However, this is probably not an important issue in premenopausal women because few of them have serum ferritin concentrations >200 μg/L.

The finding of no significant correlation between serum ferritin and dietary iron intake indicates that the loss of iron in menstrual blood in females may have a more significant effect on iron status than does dietary iron intake. More omnivores donated blood regularly, which may have contributed to their lower iron stores; however, a specific effect could not be determined and serum ferritin concentrations were not significantly different between regular blood donors and nondonors.

Conclusion

Premenopausal women consuming vegetarian or omnivorous diets need to consider their iron intake. It is important to increase women's knowledge of iron-rich foods and the dietary constituents that enhance and inhibit the absorption of nonheme iron.

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