A Vegetarian Diet Rich in Soybean Products Compromises Iron Status in Young Students[1,2]

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ABSTRACT The iron status of young Chinese Buddhist vegetarians (23 men and 32 women) and nonvegetarian students (20 men and 39 women from a medical college) was investigated by dietary assessment of iron intake and hematological measurement of biochemical indices including hemoglobin, plasma iron, transferrin, transferrin saturation and plasma ferritin. A characteristic of the vegetarian diet in this study was the replacement of meat by soybean products. Results of the dietary assessment showed that the average iron density of the diets ranged from 1.9 to 2.2 mg/MJ, with no difference between the vegetarian and nonvegetarian diets. Daily iron intake was similar in both vegetarian and nonvegetarian men. However, iron intake was significantly higher in female vegetarians than nonvegetarians, averaging 104 and 78% of the RDA, respectively. Results of blood analysis showed that, for both sexes, the median plasma ferritin concentration of the vegetarians (male 47 μg/L and female 12 μg/L) was about half the level of the nonvegetarians (male 91 μg/L and female 27 μg/L). Occurrence and risk of iron deficiency are more prevalent in vegetarians. Correlation between plasma ferritin concentration and years of vegetarian practice in vegetarian men was marginally significant ($r = -0.38$, $P = 0.077$). We conclude that a vegetarian diet that is rich in soybean products and restricted in animal foods is limited in bioavailable iron and is not adequate for maintaining iron balance in men and women. J. Nutr. 125: 212–219, 1995.

INDEXING KEY WORDS:

- *soybean-rich diet* • *plasma ferritin*
- *iron status* • *vegetarians* • *humans*
- *iron intake*

Vegetarian diets contain restricted amounts of animal products, especially fleshy foods, which are important sources of readily available heme iron and which enhance nonheme iron absorption (Hallberg 1981). In addition, such diets include abundant amounts of cereals, legumes and vegetables containing components such as phytate, fibers and soybean protein, which are inhibitory to nonheme iron absorption (Cook et al. 1981, Hallberg and Rossander 1982, Schricker et al. 1982). Therefore, one of the nutritional problems related to nutrient adequacy in vegetarian diets is iron deficiency (American Dietetic Association 1993).

Caucasian vegetarians in developed countries are no more prone to nutritional anemia than the general population (American Dietetic Association 1993). Even though women are more susceptible to iron deficiency, women eating vegetarian diets for years had normal iron indices despite their small intake of readily available iron (Anderson et al. 1981). Most such studies have been conducted with Seventh-Day Adventists or members of the Vegan Society of the United Kingdom, and both groups have a strong commitment to health and a well-informed approach to vegetarian diets. In contrast, studies of other social groups such as new vegetarians (Helman and Darton-Hill 1987) or ethnic groups such as immigrant Indians (Reddy and Sanders 1990) have suggested that some vegetarian populations may still be at risk for iron deficiency.

Few studies have examined the impact of Buddhist vegetarian diets on iron status. In general, Buddhist vegetarian diets are similar to the usual Chinese diets in terms of meal pattern, cooking methods, choice of rice as staple, and fruit and vegetable consumption (Pan et al. 1993). The major difference arises from the doctrine that it is forbidden to kill living beings. Therefore, fleshy foods are completely excluded from

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diets. Because soybean products are often substituted for animal products (Huang and Ang 1992), the primary protein sources of vegetarians are rice and soybean products (Pan et al. 1993). Several investigations have demonstrated that the percentage of iron absorption from soybean and soy products is low in humans (Cook et al. 1981, Lynch et al. 1984) and that inclusion of soybean products in a diet is inhibitory to iron absorption (Hallberg and Rossander 1982, Lynch et al. 1985). However, the long-term effect of a vegetarian diet rich in soybean products on iron status has not been directly evaluated in humans. Compared with the Seventh-Day Adventist diets (American Dietetic Association 1993), soybean products were more important in the Buddhist vegetarian diets in this study, because soybean products were included in the Buddhist diets in greater quantities than whole grains, nuts, dried fruits and legumes. The present study compared the intake and status of iron in a group of Chinese Buddhist vegetarian students with a group of nonvegetarian students by using hemoglobin, plasma transferrin, plasma iron, transferrin saturation and plasma ferritin as the principle biochemical indices.

SUBJECTS AND METHODS

Subjects. The project was conducted from December 1990 to January 1991. Subjects were initially recruited for the investigation of hemostatic and lipid profiles in Buddhist vegetarians and nonvegetarians. The detailed description of recruitment, dietary assessment and blood collection was presented in a previous report (Pan et al. 1993).

In brief, the subjects included 55 vegetarians (23 men and 32 women) from Yuan-Guan Buddhist College, Chung-Li, Taoyuan, Taiwan, and 59 nonvegetarians (20 men and 39 women) from the Departments of Nursing and Medicine at the National Defense Medical School, Taipei, Taiwan. All subjects met the following requirements: age <30 y, no history of hypertension, coronary heart disease or diabetes, nonsmokers and nondrinkers. The vegetarians were expected to have consumed vegetarian diets for >2 y. All the women studied were nulliparous. Informed consent forms were signed by all participants. The study protocol was approved by the Institute of Biomedical Sciences as ethical when the research proposal was reviewed. The characteristics of the subjects, including age, height, weight and use of nutrient supplement, are listed in **Table 1**.

Dietary data. Subjects were served breakfast, lunch and dinner in the school dining hall, and dietary intakes for each individual were assessed using a food weighing method. All served foods were weighed before and after meals for three consecutive days on two occasions that were 1.5 mo apart. The number of exchanges of various food groups was calculated according to the United States exchange system (American Dietetic Association 1986). The energy intake was calculated from the contents of carbohydrate, protein and lipid after proximate analysis (Pan et al. 1993). Intakes of iron, vitamin C and crude fiber were calculated by using food composition tables (Huang et al. 1978, Tung et al. 1961). The mean nutrient intakes per day were calculated by averaging intakes for the 6 d. The dietary iron density is expressed as milligrams of iron per megajoule.

Blood analysis. Venous blood samples were collected from fasting subjects, using Vacutainers containing sodium heparin (Sherwood Medical, St. Louis,

TABLE 1

Subject characteristics[1]

	Male		Female	
	Nonvegetarian (n = 20)	Vegetarian (n = 23)	Nonvegetarian (n = 39)	Vegetarian (n = 32)
Age, *y*	20.6 ± 1.0	22.6 ± 4.4[a]	20.3 ± 1.1	24.8 ± 4.0[b]
Height, *cm*	171.7 ± 4.1	168.1 ± 4.9	161.1 ± 4.1	158.5 ± 6.1
Weight, *kg*	62.7 ± 3.7	56.4 ± 6.5	53.7 ± 5.9	50.4 ± 8.0
Body mass index, *kg/m²*	21.3 ± 1.2	20.0 ± 1.3[a]	20.7 ± 2.6	20.1 ± 2.8
Duration of vegetarian diets, *y*	0	5.5 ± 4.6	0	6.7 ± 6.2
Supplementation, *no. of users*				
Multivitamins	5	6	2	4
Vitamin C	2	2	2	2
Vitamin B	1	0	0	2
Vitamin E	0	0	0	1
Calcium	0	0	0	2

[1]Values are means ± SD. Superscripts indicate a significant difference between dietary groups within sex according to Student's t test: [a]$P \le 0.05$, [b]$P \le 0.001$.

MO). Whole blood used for hemoglobin measurement was collected using a paper disc method (Feraudi and Mejia 1987). The plasma was immediately separated by centrifugation at 4°C and 3000 × g for 15 min, and aliquots were placed into plastic vials. Plasma samples were placed on dry ice for transport and stored in a freezer at −70°C until analysis.

The hemoglobin concentration was measured according to the cyanomethemoglobin method (Oser 1965). Plasma transferrin was measured using a turbidimetric immunoassay kit (Boehringer Mannheim GmbH, Mannheim, Germany). The total iron-binding capacity was calculated from the concentration of transferrin. Plasma ferritin was determined by a two-site immunoradiometric assay (Allegro Ferritin, Nichols Institute, Geneva, Switzerland). Plasma iron was measured using a diagnostic iron kit (Test Combination, Boehringer Mannheim GmbH). For quality control of clinical analyses, control serum Lyphochek (BIO-RAD, Anaheim, CA) was incorporated in ferritin assay, and Precinorm U and Precipath U (Boehringer Mannheim GmbH) were used in iron and transferrin assays.

Criterion of anemia was set at hemoglobin <8.1 mmol/L for males and <7.4 mmol/L for females (FAO/WHO 1968). Criterion of iron depletion was set at serum ferritin <12 μg/L for both men and women (Cook and Finch 1979).

Statistical analysis. All data except plasma ferritin were presented as means ± SD. Data were subjects to ANOVA. Differences in subject characteristics between dietary groups within each sex were tested using Student's *t* test. Differences in nutrient intakes and iron status were compared among four groups by Duncan's multiple range test (Remington and Schork 1985). Ferritin concentrations were reported as medians and ranges and were log-transformed before analysis because they were not normally distributed. Correlation between variables were evaluated by Pearson product moment analysis. The significance level was set at $P \leq 0.05$ for all statistical analyses. All statistical procedures were performed on the SAS System (SAS Institute, Cary, NC).

RESULTS

The two dietary groups (vegetarian and nonvegetarian) were of comparable age and body size (Table 1). Although the vegetarian groups were slightly older than the nonvegetarian groups and the nonvegetarian males had a slightly greater body mass index than the vegetarian males, these differences were not expected to impair the comparison of iron status. The duration of vegetarian practice ranged from 2 to 23 y, which was expected to be sufficient to demonstrate dietary effects on individual iron status. More vegetarian subjects took nutrient supplements than their nonvegetarian peers (30 vs. 20%), but none of the subjects used any iron-containing supplements.

Dietary intakes. The number of exchanges served to the vegetarians was 15 and 3.5 for rice and soybean products, respectively, whereas that served to the nonvegetarians was 14 and 1, respectively. Food distribution of iron was as follows: for vegetarians, staple 45.1%, vegetables 32.9%, soybean products 17.5%, fruits 1.9%, dairy 0.2%, other 2.4%; for nonvegetarians, staple 36.4%, animal products (meat, fish and egg) 33.5%, vegetables 15.8%, soybean products 8.6%, fruits 4.9%, dairy 0.3%, other 0.5%.

The average iron density of the diets ranged from 1.9 to 2.2 mg/MJ, and there was no difference between the vegetarian and nonvegetarian diets (**Table 2**). Intakes of energy, iron, vitamin C and crude fiber were not significantly different between the male vegetarians and male nonvegetarians. The average daily iron intakes were 16.1 and 18.4 mg for the two male groups, which were higher than the RDA for iron (10 mg/d) (NRC 1989). The protein intake was lower in the vegetarians, but it was no lower than the RDA of 63 g/d (NRC 1989). There were some differences in nutrient intakes between the two female groups. The female nonvegetarians had a mean iron intake of 11.7 mg/d, which was lower than the RDA (15 mg/d) (NRC 1989), and only 49% of the subjects reached 80% RDA; the female vegetarians had a mean iron intake of 15.6 mg/d, which was about equal to RDA, and 78% of the subjects reached 80% RDA. The intakes of energy and iron were significantly higher and those of vitamin C and crude fiber were significantly lower in the vegetarians than in the nonvegetarians. The protein intake was similar in both female groups, and it was no lower than the RDA of 50 g/d (NRC 1989).

The correlation between dietary energy and iron intakes was significant for the nonvegetarian groups (male $r = 0.69$, female $r = 0.83$) as well as for the vegetarian groups (male $r = 0.43$, female $r = 0.33$); the correlation for vegetarians was weaker, an indication of the slight disparity of the food sources of the two nutrients.

Blood analysis. Results of biochemical indices of iron status are listed in **Table 3**. In general, the female subjects exhibited inferior iron status compared with males regardless of dietary practices, as indicated by symptoms such as anemia and iron depletion.

The comparison between vegetarians and nonvegetarians demonstrated that vegetarians had an iron status inferior to that of nonvegetarians for both sexes (Table 3). For males, the iron status in nonvegetarians was normal and anemia or iron depletion was absent as indicated by normal values of all the measured iron indices. The frequency distribution patterns of plasma ferritin and transferrin levels were different between the two male groups (**Fig. 1***A* and 1*B*), and vegetarians had significantly lower ferritin and elevated transferrin concentrations. The median value of plasma

TABLE 2

Daily nutrient intakes of energy, protein, iron, vitamin C and fiber[1]

	Male		Female	
	Nonvegetarian (n = 20)	Vegetarian (n = 23)	Nonvegetarian (n = 39)	Vegetarian (n = 32)
Dietary Fe density, *mg/MJ*	1.9 ± 1.2	2.2 ± 0.8	2.0 ± 0.3	2.0 ± 0.7
Energy intake, *MJ/d*	8.4 ± 1.3^{a}	8.4 ± 1.3^{a}	5.9 ± 1.2^{b}	7.8 ± 1.6^{a}
Protein, *g/d*	80 ± 13^{a}	72 ± 16^{b}	62 ± 12^{c}	69 ± 17^{bc}
Fe, *mg/d*	16.1 ± 2.9^{ab}	18.4 ± 7.3^{a}	11.7 ± 2.6^{c}	15.6 ± 5.4^{b}
<100% RDA,[2] *n*	0	1	37	19
Crude fiber, *g/d*	5.6 ± 2.2^{ab}	5.0 ± 1.7^{ab}	6.1 ± 2.7^{a}	4.7 ± 1.0^{b}
Vitamin C, *mg/d*	155 ± 85^{b}	132 ± 52^{b}	196 ± 98^{a}	137 ± 41^{b}

[1]Values are means ± SD. Within a row, values with different superscripts differ significantly by Duncan's multiple range test ($P \leq 0.05$).
[2]The RDA for iron is 10 mg/d for male and 15 mg/d for female (NRC 1989).

ferritin in vegetarians was only half that of their nonvegetarian peers. Unexpectedly, in vegetarian men, the plasma iron concentration and transferrin saturation were not reduced, but were 44 and 33% higher, respectively, than in their nonvegetarian peers. Although the vegetarian men showed no anemia or iron depletion, the correlation between plasma ferritin and transferrin was significant (r = −0.5), and correlation between the duration of vegetarian practice and plasma ferritin concentrations was marginally significant (r = −0.38, P = 0.077, **Fig. 2**).

For females, the iron status of the nonvegetarians was unsatisfactory as reflected by the presence of five anemic subjects, nine iron-depleted subjects and 15 subjects with elevated total iron-binding capacity. Plasma iron and transferrin saturation levels for the female nonvegetarians were within the normal range. The median value of plasma ferritin was 27 μg/L. The frequency distribution of plasma ferritin and transferrin shown in Figure 1*C* and 1*D* presented patterns skewed toward lower ferritin and elevated transferrin.

The vegetarian women had significantly lower hemoglobin and ferritin concentrations than the

TABLE 3

Hematological indices of iron status in vegetarians and nonvegetarians[1]

	Male		Female	
Index	Nonvegetarians (n = 20)	Vegetarians (n = 23)	Nonvegetarians (n = 39)	Vegetarians (n = 32)
Hemoglobin, *mmol/L*	9.4 ± 0.2^{a}	9.2 ± 0.5^{a}	7.9 ± 0.5^{b}	7.6 ± 0.9^{c}
Anemic subjects,[2] *n*	0	0	5	10
Transferrin, *μmol/L*	32 ± 4^{b}	35 ± 4^{a}	35 ± 4^{a}	36 ± 7^{a}
TIBC,[3] *μmol/L*	64 ± 8^{b}	69 ± 9^{ab}	69 ± 9^{ab}	72 ± 14^{a}
>71 *μmol/L n*	3	6	15	12
Plasma iron, *μmol/L*	16 ± 6^{b}	23 ± 5^{a}	17 ± 7^{b}	17 ± 7^{b}
Transferrin saturation, %	27 ± 12^{b}	36 ± 8^{a}	27 ± 12^{b}	26 ± 13^{b}
<15%, *n*	2	0	3	7
Plasma ferritin,[4] *μg/L*	91^{a} (37–532)	47^{b} (9–182)	27^{c} (3–145)	12^{d} (3–74)
<12 *μg/L*,[5] *n*	0	1	9	15

[1]Values are means ± SD. Within a row, values with different superscripts differ significantly by Duncan's multiple range test ($P \leq 0.05$).
[2]Cutoff hemoglobin values for anemia are 8.1 mmol/L for males and 7.4 mmol/L for females (FAO/WHO 1968).
[3]TIBC = total iron-binding capacity.
[4]Values are medians with ranges in parentheses. Median plasma ferritin values for all groups were significantly different by Duncan's multiple range test ($P \leq 0.05$), after log transformation of data.
[5]Number of subjects who had a ferritin concentration lower than the indicated value. The value of 12 μg/L indicates depletion of iron storage (Cook and Finch 1979).

nonvegetarian women, but the transferrin level was comparable in both groups. The median value of plasma ferritin was 12 μg/L, which was only half that of the nonvegetarians and was at the borderline of iron depletion. Frequency distribution patterns were similar for both female groups (Fig. 1*C* and 1*D*), but low ferritin was more prevalent in the vegetarians. The prevalences of anemia and iron depletion were 30 and 50%, respectively, in the female vegetarians, which were more than twice the values for the female nonvegetarians (12.5 and 22.5%, respectively). Unlike the findings for males, the correlation between the duration of vegetarian practice and ferritin levels was not significant (Fig. 2).

Results of the correlation analysis of iron indices are listed in **Table 4**. The four groups exhibited very different patterns, and the pooled results were also different from the individual groups. No correlation was found in nonvegetarian males, whereas an inverse correlation existed between ferritin and total iron-binding capacity in vegetarian males. The inverse correlation was lost when two male groups were pooled. The correlation between hemoglobin and transferrin saturation and plasma iron in nonvegetarian females was not found in the vegetarian females. When the four groups were pooled, the correlation between hemoglobin concentration and iron intake was significant ($r = 0.26$, $P = 0.005$), whereas that between ferritin and iron intake was only marginally significant ($r = 0.17$, $P = 0.064$). Such correlations did not exist in individual groups.

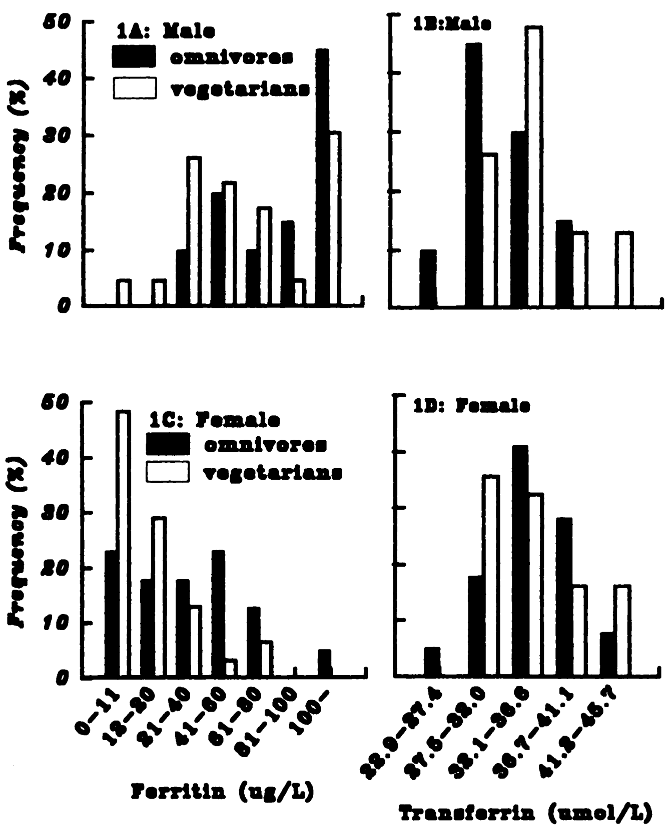

FIGURE 1 Frequency distribution of plasma ferritin (*A*) and transferrin concentrations (*B*) in male nonvegetarians (20 subjects) and vegetarians (23 subjects), and frequency distribution of plasma ferritin (*C*) and transferrin (*D*) concentrations in female nonvegetarians (39 subjects) and vegetarians (32 subjects). The vegetarians had consumed a vegetarian diet rich in soybean products for at least 2 y.

DISCUSSION

Iron status is generally less adequate in menstruating women than in their male peers (NRC 1989). The underlying reasons are physiological, because women have increased iron loss due to menstruation and lower iron intake due to lower energy consumption (Finch and Cook 1984). In this study, the gender difference and the relationship between energy and iron intake were also observed in the two dietary groups (vegetarian and nonvegetarian). For nonvegetarian women, the first limiting factor was energy intake. If energy intake is increased from 5.9 to 7.5 MJ/d, iron intake can be increased from 11.6 to ~15 mg/d.

In this study, the prevalence of iron depletion in both nonvegetarian groups was consistent with that estimated for the male and female populations age 16 to 44 y in Taiwan, which was about 2 and 20%, respectively (unpublished data). Although some subjects took vitamin or mineral supplements, the percentage is relatively low when compared with

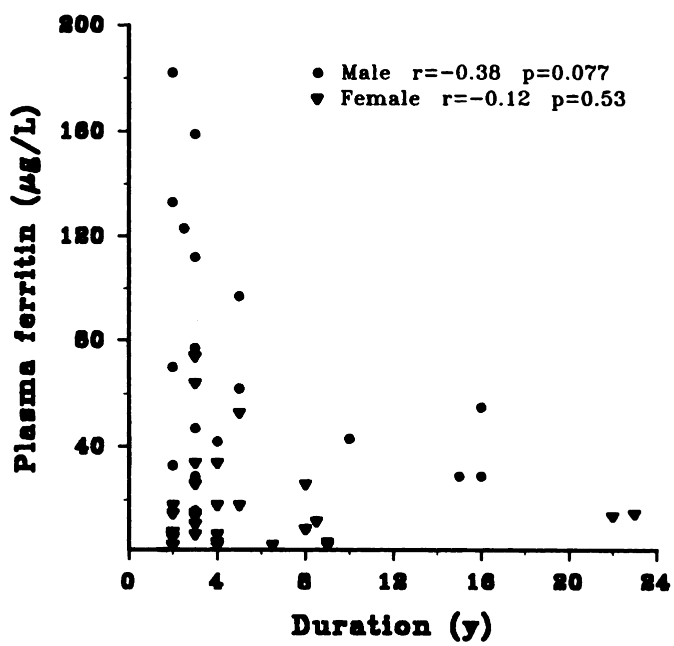

FIGURE 2 Correlation between plasma ferritin concentration and years of vegetarian practice in 32 women and 23 men consuming a vegetarian diet rich in soybean products for at least 2 y.

TABLE 4

Pearson's correlation coefficients between hematological indices of iron status[1]

Hematological indices[2]	Male Nonvegetarian	Male Vegetarian	Male Pooled	Female Nonvegetarian	Female Vegetarian	Female Pooled	Pooled
Hb vs. Fer	NS	NS	NS	NS	NS	NS	NS
Hb vs. TIBC	NS	NS	NS	NS	NS	NS	–0.23
Hb vs. TS	NS	NS	NS	0.40	NS	0.34	0.25
Hb vs. PFe	NS	NS	NS	0.49	NS	0.38	0.25
Fer vs. TIBC	NS	–0.50	NS	–0.50	–0.48	–0.43	–0.25
Fer vs. TS	NS	NS	NS	0.38	0.59	0.41	NS
Fer vs. PFe	NS	NS	NS	NS	0.50	0.32	NS
TIBC vs. PFe	NS	NS	NS	NS	–0.44	–0.33	–0.21

[1]The level of significance is $P \leq 0.05$. NS = not significant.
[2]Hb = hemoglobin, Fer = plasma ferritin, TIBC = total iron binding capacity, TS = transferrin saturation and PFe = plasma iron.

Western vegetarians (Shultz and Leklem 1983). No subject took any supplement containing iron. This may imply that the general population in Taiwan is not aware of the risk of iron deficiency, because the dietary iron intake was estimated to be 16.9 mg/d per person in the National Dietary Survey conducted in Taiwan in 1986–1988 (Lee et al. 1991).

Unlike in Western societies, food is not routinely fortified with iron in Taiwan. Therefore, iron naturally present in foods is the major dietary source. Iron density of the diets in this study (1.9–2.2 mg/MJ) was either comparable with or higher than that in the Western diets (1.2–2.2 mg/MJ) (Adbulla et al. 1981, Anderson et al. 1981, Shultz and Leklem 1983). Daily iron intake for our subjects was also comparable to that reported for the corresponding Western populations including Caucasian women of reproductive age (Worthington-Roberts et al. 1988), Seventh-Day Adventists (Shultz and Leklem 1983), Swedish vegetarians (Abdulla et al. 1981), "new" vegetarians (Helman and Darton-Hill 1987) and immigrant Indians (Reddy and Sanders 1990). Therefore, our result is consistent with these reports that vegetarian diets were no poorer in total iron content than the nonvegetarian ones. The correlation between iron and energy intake in the vegetarian groups was not as strong as in the nonvegetarian groups. This can be explained by the difference in food distribution: for vegetarians, 35% of iron came from fruits and vegetables and only 63% from foods abundant in energy-containing nutrients, whereas for nonvegetarians, the percentages were 21 and 79%, respectively. Because the nonvegetarians consumed more fruits than did the vegetarians, this probably contributed to the higher intake of fiber and vitamin C in the former group.

Both vegetarian groups (male and female) had an iron intake close to or higher than the RDA, yet both showed impaired iron status, indicating that bioavailability was the major determinant of the iron adequacy of a vegetarian diet. Bioavailability was obviously impaired by an imbalance between enhancers and inhibitors. Soybean products are a rich source of iron, but their components such as the protein fraction and phytate are inhibitory to iron absorption (Cook et al. 1981, Hallberg and Rossander 1982, Lynch et al. 1984 and 1985); therefore, they do not provide net benefit in vegetarian diets. Exclusion of meat not only removes highly available heme iron, but also decreases the ability to counterbalance powerful inhibitors such as soybean protein. Others have reported a correlation between meat consumption and iron status in men and women (Takkunen and Seppanen 1975, Worthington-Roberts et al. 1988). This study confirms the importance of meat in iron nutriture, because nonvegetarian women consumed only 74% as much iron as the vegetarians, but their iron status was better. Although vitamin C enhances absorption of nonheme iron (Hallberg 1981), simultaneous occurrence of both vitamin C and iron in the gut is necessary for effective interaction. The major food contributors of vitamin C are vegetables and fruits (Pan et al. 1992). In Chinese diets, vegetables are commonly stir-fried, and fruit juice or fresh fruits are seldom eaten with a meal. Therefore, the benefit of vitamin C is compromised by heat susceptibility and separate consumption.

The mean percentage absorption from the vegetarian diet was estimated to be <5.4%, because 1 mg of iron daily is required to maintain iron balance in humans (NRC 1989), and an average intake of 18.6 mg was not sufficient for iron balance. The value was consistent with the range reported by Cook et al. (1991), who found that absorption from diets rich in inhibitors ranged from 1.8 to 3.4% in subjects with a wide range of iron status. It is inferred from these results that the increased absorption in individuals with poor iron status cannot fully compensate for the limitations in bioavailability, and absorption of nonheme iron probably remained low in iron-depleted subjects. The estimated 10% absorption in the derivation of the RDA for iron (NCR 1989) is not applicable in pure vegetarians, and this must be clearly understood as vegetarianism becomes increasingly popular. For improvement of iron status in vegetarians, supplementation with vitamin C may be helpful, but the effect has not been validated (Cook et al. 1984, Hunt et al. 1990). Iron supplementation is expected to be more effective.

The hematological outcome in vegetarian men deserves some attention. The plasma iron and transferrin saturation were within the normal range but significantly elevated (144 and 133%, respectively) above the level in their nonvegetarian peers. This is in contrast with the consensus that both serum iron and transferrin saturation fall in uncomplicated iron deficiency (Cook and Finch 1979). However, a similar observation was reported by Pirzio-Biroli and Finch in 1960. In a 2-y study of the influence of iron stores on iron absorption, they reported elevated plasma iron for a period of 1.5 y in four iron-depleted young men age 20 to 30 y. The subjects had normal hemoglobin values, and iron depletion was obtained by six phlebotomies. The mean values for serum iron, total iron-binding capacity, and transferrin saturation were 23.6 μmol/L, 56.6 μmol/L and 43.5%, respectively, and were 125, 105 and 120%, respectively, as much as the level in the iron-loaded men. On the basis of these results, the authors speculated that some adaptive mechanisms existed and helped to increase the efficiency of iron utilization when iron stores were depleted gradually. Because dietary iron was adequate, iron supply to the body was expected to increase due to increased iron absorption (Abdulla et al. 1981, Pirzio-Biroli and Finch 1960) and reduced fecal iron loss in vegetarians (Kies and McEndree 1982). The combination of elevated iron transport and reduced iron storage implied that the priority of iron utilization was not for storage but for maintenance of a readily mobile iron pool. Under such circumstances, iron supply to erythropoietic tissue was sufficient to maintain normal erythropoietic function and a normal hemoglobin level. However, this was probably a transition stage between iron depletion and iron-deficient erythropoiesis, and long-term consumption of a vegetarian diet was not without risk in men, because plasma ferritin and duration of vegetarian practice were inversely related, implying a negative iron balance during that time. Even a slightly negative iron balance daily will eventually exhaust the small iron stores and result in iron deficiency and anemia in advanced age. We speculate that vegetarian men may face an increased risk of iron deficiency as age advances.

In vegetarian women, the adaptive machinery mentioned above was expected to be functioning, because the mean plasma iron and transferrin saturation were maintained in normal range. But the capacity of adaptation was not sufficient to compensate for the large iron loss due to menstruation; in consequence the mobile iron pool in plasma was smaller in women than in men. Lack of a correlation between plasma ferritin and years of vegetarian diets can be explained by the narrow range of ferritin level and a high frequency (48%) of subjects with ferritin of <12 μg/L. Longer duration of vegetarianism still contributed to impaired iron status, because the frequency of iron depletion was higher in subjects consuming vegetarian diets for >6 y than in those consuming such diets for <6 y (55.5 vs. 39%).

In conclusion, a vegetarian diet rich in soybean products and completely restricted in animal foods is limited in bioavailable iron and is not adequate to maintain iron balance in young men and women.

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