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Nutrition Research, Vol. 19, No. 5, pp. 663–674, 1999

0271-5317/99/$–see front matter

PII S0271-5317(99)00031-7

NUTRIENT INTAKES AND IRON STATUS OF HEALTHY YOUNG VEGETARIANS AND NONVEGETARIANS

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ABSTRACT

Nutritional intake and iron status were investigated in 35 vegetarians (15 vegetarian males, 20 vegetarian females) and 32 nonvegetarians (13 vegetarian males, 19 nonvegetarian females). Each subject completed a 12-d diet record. Hemoglobin, plasma iron, ferritin, total iron binding capacity, and transferrin saturation were measured. Vegetarians had lower dietary fat, protein, fiber, vitamin A, iron, cholesterol and sodium intakes than nonvegetarians. No significant differences were found in carbohydrate, thiamin, vitamin C, and calcium intakes between the 2 major groups. Although vegetarians had lower iron intake than nonvegetarians, their iron intake was 275% and 142% above the Taiwan Recommended Daily Nutrient Allowance (RDNA) for vegetarian males and females ($p < 0.05$), respectively. One vegetarian female was in an anemia stage with a plasma iron level of 32 µg/dL; 2 female subjects (1 vegetarian, 1 nonvegetarian) had anemic ferritin levels (< 10 ng/mL); 5 vegetarian females and 1 nonvegetarian female subject had anemic total iron binding capacity levels > 410 µg/dL; and 3 vegetarian males, 6 vegetarian females and 1 nonvegetarian female showed anemia with transferrin saturation < 15%. Six vegetarian females and 1 nonvegetarian female were anemic because they had two or more abnormal biochemical indices of iron status. Although vegetarian subjects had sufficient iron intake, the bioavailability of iron seemed limited to maintaining iron balance, especially in women.

KEY WORDS: Nutrient intakes, Iron, Status, Vegetarian, Nonvegetarian

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INTRODUCTION

Vegetarians have lower incidence of hypertension, coronary artery disease, type II diabetes, and gallstone (1). However, there is concern that some vegetarians may not obtain adequate amounts of iron. Vegetarians have an iron intake closer to or higher than omnivores (2-4), but showed impaired iron status, indicating that the bioavailability of iron may be affected on some vegetarian diets. Vegetarian diets contain restricted amount of animal products, especially fleshy foods, which are important sources of readily available heme iron and which enhance nonheme iron absorption (5). Instead, the major sources of dietary iron for vegetarians are vegetables, fruits, whole grain cereals, legumes, and nuts, which also contain phytates (4,6), polyphenols (7) and soybean protein (5), which interfere with nonheme iron absorption. However, vitamin C found in fruits and vegetables is a good enhancer of nonheme iron absorption (8,9). Because heme iron is generally much more easily absorbed (15-35%) than is nonheme iron (2-20%), it has been suggested that vegetarians may be at greater risk of iron deficiency (8).

A number of studies have been performed to assess the adequacy of iron intake and iron status in vegetarians. Marr and Heady (10) indicated that 12-14 d dietary records are needed to provide good estimates of true long-term intake. Kelsay et al. (11) reported that vegetarians had a higher iron intake than omnivores by using detailed 14-d diet records; however, other studies (12, 13) showed similar or lower intakes. Serum ferritin was one of the most commonly deficient biochemical indices in vegetarians, particularly among women (14). Low serum ferritin levels were found in 5% of male and 27% of female vegetarians, with 10% of women having values < 10 ng/mL (14). However, determination of serum ferritin alone is not considered sufficient to assess iron status. Cook et al. (15) indicated that the prevalence of anemia among individuals with only one abnormal index of iron status was slightly higher than in the entire population. As previously recommended (15-17), the use of multiple iron status indicators (i.e., plasma ferritin, total iron binding capacity (TIBC), unsaturated iron binding capacity (UIBC), transferrin saturation, hemoglobin) simultaneously provides a more accurate measure of iron status than any single index.

Food is not routinely fortified with iron in Taiwan. Huang and Ang (18) have reported that soybean products are often substituted for animal products in Chinese Buddhist vegetarian diets, and the primary protein sources of vegetarians are rice and soybean products (19). Exclusion of meat not only eliminates highly available heme iron, but also decreases the ability to counterbalance inhibitors such as soybean protein. Therefore, particular attention must be given to those subjects whose diet is more heavily dependent on plant products and who consume less meat. The purpose of this study was to investigate the nutrient intakes and examine the iron status of young vegetarian adults compared to omnivores.

SUBJECTS AND METHODS

Subjects

Vegetarian and nonvegetarian adults were recruited from the University community by advertisements. For the purpose of this study, a vegetarian was defined as someone who ate neither meat nor fish. Potential subjects were interviewed personally by one of the principal investigators, at which time the study was explained and interest determined. Demographic and health data were collected and weight and height were measured. A fasting blood sample was obtained for clinical chemistry evaluation. Subjects had to meet the following criteria for inclusion in this study: 1) age < 40 y; 2) no illness or medical condition requiring a physician's supervision; 3) no history of heart, liver, or kidney diseases, diabetes, alcoholism, cancer, hypertension, menstrual irregularities, reproductive problem, or other metabolic diseases; 4) no history of hormonal therapy (i.e., oral contraceptives) or other drugs (i.e., antacids, aluminum hydroxide, tetracyclines) which would influence iron status and metabolism; 5) a history of consuming a vegetarian diet > 2 year for vegetarian subjects; 6) normal blood chemistry evaluations; 7) no weight change exceeding ± 4 kg within the last year; 8) no pregnant subjects.

Thirty-eight vegetarians (16 males, 22 females) and 34 nonvegetarians (14 males, 20 females) were recruited in this study from Taichung city, Taiwan. However, 3 vegetarians (1 male, 2 females) and 2 nonvegetarians (1 male, 1 female) dropped out before the end of the study for personal reasons. Thus, data are reported on 35 vegetarians and 32 nonvegetarians who completed the entire study. Subjects' characteristics are summarized in Table 1. Informed consent was obtained from each subject. The study protocol was approved as ethical when the research proposal was reviewed by the Chung-Shan Medical and Dental College.

Dietary data and sampling procedures

All subjects were given instruction on how to complete a 12-d dietary record for 3 consecutive days (2 weekdays and one weekend day) each week, over a 4-week period. Subjects were asked to write down the times food, including supplements are eaten, all food and beverages consumed, the amounts consumed, and methods of preparation. Nutrient composition of the 12-d records was calculated using the food composition table (Department of Health, Taiwan, 1994). The results of nutrient data were compared to the Taiwan RDNA (Department of Health, Taiwan, 1993).

Once the dietary record had been completed, fasting venous blood samples were obtained to estimate hematological and iron status parameters. Blood specimens were collected in Vacutainer tubes (Becton Dickinson, Rutherford, NJ) containing an appropriate anticoagulant (EDTA or Heparin). The plasma was immediately separated by centrifugation, and stored frozen (-80° C) until analysis.

The hemoglobin concentration was determined on a Automatic Analyzer (ARCO; Biotecnica Instruments, Italy). Plasma ferritin was measured by a 2-site immunoradiometric assay kit (INCSTAR Corporation, Stillwater, MN). Plasma iron and TIBC were determined using the iron/UIBC/TIBC commercial kit (Sigma Chemical Co., St. Louis, MO). The percent saturation of plasma transferrin was calculated using the following formula: plasma transferrin = plasma iron (μg/dL) × 100 / TIBC.

Statistical analysis

Data were analyzed by using the SigmaStat statistical software (version 1.0; Jandel Scientific, San Rafael, CA). Differences in subject characteristics between dietary groups within each sex were determined by use of the Student's *t* test. One-way analysis of various (ANOVA) was used to compare the differences in nutrient intakes and biochemical measurements among the groups. Pearson correlation coefficients were performed to assess the relationship between dietary variables and iron status parameters. Statistical results were considered to be significant at $p \leq 0.05$. Values presented in the text are means ± standard deviation (SD).

RESULTS

Descriptive characteristics

Characteristics of vegetarian and nonvegetarian subjects are shown in Table 1. The two groups (vegetarian vs. nonvegetarian) were of comparable age and body size, although the vegetarian females were slightly older than the nonvegetarian females and the nonvegetarian males had a slightly greater body weight and body mass index than the vegetarian males. These differences were not expected to affect the comparison of nutrient intakes and iron status. Vegetarian males and females had been following this diet practice for a mean of 4 and 3.5 years, respectively. Five (1 male, 4 females) nonvegetarian subjects and 4 (1 male, 3 females) vegetarian subjects took either B-complex, vitamin C, vitamin E or multivitamin supplements. However, the amount of their nutrient supplements was not included in their dietary intakes.

TABLE 1

Descriptive Characteristics of Vegetarian (V) and Nonvegetarian (NV) Subjects

	Male		Female	
Characteristics	V (n=15)	NV (n=13)	V (n=20)	NV (n=19)
Age (y)	23.6 ± 4.9*	22.7 ± 2.0	25.5 ± 6.1[a,#]	21.7 ± 1.1[b]
Height (cm)	171 ± 4.9	173 ± 5.3	158 ± 4.7	158 ± 4.1
Weight (kg)	62.7 ± 5.1[b]	71.8 ± 8.4[a]	50.6 ± 6.3	50.9 ± 7.1
BMI (kg/m^2)	21.5 ± 2.3[b]	23.9 ± 2.3[a]	20.3 ± 2.6	20.4 ± 2.9

* Values are mean ± SD

\# Values with different superscript letters are significantly different between dietary groups within sex; $p \leq 0.05$

Dietary intakes

Nutrient intakes from the 12-d dietary records kept by the subjects were calculated (Table 2). Nonvegetarian males had a significantly higher energy intake than vegetarian and nonvegetarian females, while there was no significant difference between vegetarian and nonvegetarian males. There was no significant difference in iron intake between vegetarian and nonvegetarian male subjects. However, nonvegetarian females had a significantly higher iron intake than vegetarian females. The intake of dietary fat, cholesterol and sodium was significantly lower in vegetarians than nonvegetarians. No significant differences were found in carbohydrate, thiamin, riboflavin, niacin, vitamin C, vitamin E, and calcium intake between vegetarian and nonvegetarian groups for both sexes. When intake of the energy-providing nutrient was expressed as a percentage of total caloric consumption, vegetarians had a significantly higher mean percentage of carbohydrate than nonvegetarians (72% vs. 61% males; 70% vs. 60% females, respectively) and a lower mean percentage of fat (15% vs. 24% males; 19% vs. 26% females, respectively) and protein (16% vs. 20% males; 16% vs. 19% females, respectively).

TABLE 2

Daily Nutrient Intakes in Vegetarian (V) and Nonvegetarian (NV) Subjects

Nutrients	Male		Female	
	V (n =15)	NV (n =13)	V (n =20)	NV (n =19)
Energy (kcal)	2285.7 ± 693.2[a,b]	2377.1 ± 578.4[a]	1494.2 ± 404.6[c]	1774.1 ± 381.1[b,c]
Iron (mg)	27.5 ± 20.7[b,c]	45.7 ± 21.7[a,b]	21.3 ± 19.5[c]	34.5 ± 19.1[b]
Carbohydrate (g)	381.7 ± 108.5[a]	364.2 ± 96.6[a]	257.7 ± 63.4[b]	265.6 ± 67.5[b]
(% total energy)	71.9 ± 6.8[a]	61.1 ± 4.1[b]	69.5 ± 4.7[a]	59.5 ± 4.9[b]
Lipid (g)	37.1 ± 16.5[c]	63.1 ± 15.9[a]	32.4 ± 15.9[c]	50.3 ± 10.6[b]
(% total energy)	15.4 ± 4.5[c]	24.1 ± 3.8[a]	18.7 ± 4.1[b]	25.8 ± 4.4[a]
Protein (g)	85.7 ± 37.8[a,b]	120.1 ± 37.1[a]	61.6 ± 21.9[b]	85.5 ± 26.9[a]
(% total energy)	15.8 ± 3.8[b]	20.0 ± 2.3[a]	16.4 ± 3.3[b]	19.1 ± 2.9[a]
Cholesterol (mg)	129 ± 124[b]	345 ± 141.7[a]	104.6 ± 105[b]	277.6 ± 67.2[a]
Dietary fiber (g)	9.4 ± 10.2[b,c]	17.9 ± 10.8[a]	7.5 ± 5.6[c]	13.4 ± 8.3[a,c]
Thiamin (mg)	1.2 ± 1.1	1.5 ± 0.9	1.1 ± 1.4	1.2 ± 0.8
Riboflavin (mg)	1.1 ± 0.9	2.1 ± 1.0	1.0 ± 1.0	1.6 ± 0.9
Niacin (mg)	18.5 ± 19.2	30.2 ± 14.8	12.1 ± 14.5	25.7 ± 22.8
Vitamin C (mg)	102.6 ± 68.1	164.1 ± 90.6	123.5 ± 86.7	158.1 ± 126.7
Vitamin A (IU)	6520 ± 4970[b]	13700 ± 8640[a]	5760 ± 4120[b]	9850 ± 7220[a,b]
Vitamin E (mg)	40.6 ± 17.0	39.7 ± 27.0	36.4 ± 17.5	22.7 ± 7.2
Calcium (mg)	626.5 ± 315.5[b,c]	823.4 ± 242.6[a,b]	562.0 ± 315.2[c]	608.1 ± 278.8[b,c]
Sodium (g)	3.4 ± 3.1[b]	18.3 ± 12.4[a]	4.9 ± 5.7[b]	16.6 ± 5.5[a]

[#] Values are mean ± SD; values within a row with different superscript letters are significantly different; $p \leq 0.05$

The mean energy intake of both vegetarian and nonvegetarian males was higher than the current Taiwan RDNA of 2200 kcal/d (Department of Health, Taiwan, 1993). However, both vegetarian and nonvegetarian females had mean energy intake lower than the Taiwan RDNA of 1800 kcal/d (Department of Health, Taiwan, 1993). All subjects had a mean intake of protein, thiamin, riboflavin, niacin, vitamin C, A, E, and iron higher than the Taiwan RDNA. A large proportion of both vegetarian males, females and nonvegetarian males, and females had calcium intakes below the Taiwan RDNA (67%, 75%, 15%, and 63%, respectively below 600 mg/d).

The correlation between dietary energy and iron intakes was significant for the vegetarian groups ($r = 0.4, p < 0.05$) as well as for the nonvegetarian groups ($r = 0.64, p < 0.01$). A similar result was seen between dietary protein and iron intake in vegetarian ($r = 0.6, p < 0.01$) and nonvegetarian groups ($r = 0.79, p < 0.01$).

Blood analyses

The results of biochemical indices of iron status in vegetarians and nonvegetarians are listed in Table 3. No significant differences were found in mean hemoglobin and plasma iron concentrations between vegetarian and nonvegetarian groups for both sexes. Nonvegetarian females showed a significantly higher mean plasma ferritin concentration than vegetarian females. Vegetarian male subjects had significantly higher TIBC levels than nonvegetarian male subjects, while vegetarian female subjects showed no difference from nonvegetarian female subjects. No significant difference in transferrin saturation was found between vegetarian and nonvegetarian groups within sex, but there was significant difference in transferrin saturation between males and females.

TABLE 3

Biochemical Indices of Iron Status in Vegetarian (V) and Nonvegetarian (NV) Subjects

Index	Male		Female	
	V (n=15)	NV (n=13)	V (n=20)	NV (n=19)
Hemoglobin (g/dL)	18.0 ± 1.8^{a}	17.2 ± 1.3^{a}	14.3 ± 1.8^{b}	15.0 ± 1.9^{b}
Plasma iron (μg/dL)	92.6 ± 40.7	105.6 ± 23.3	80.0 ± 32.1	96.6 ± 28.2
Plasma ferritin (ng/mL)	$46.2 \pm 18.1^{a,b}$	69.9 ± 22.6^{a}	17.9 ± 10.3^{c}	40.0 ± 20.9^{b}
TIBC** (μg/dL)	363.0 ± 46.3^{c}	310.3 ± 52.5^{b}	372.8 ± 52.3^{a}	$340.2 \pm 54.5^{a,b}$
TS*** (%)	26.9 ± 14.5^{a}	35.0 ± 9.6^{a}	22.4 ± 10.6^{b}	29.5 ± 10.4^{b}

* Values are mean ± SD
# Values within a row with different superscript letters are significantly different; $p \leq 0.05$
**TIBC: Total iron binding capacity; ***TS: Transferrin saturation

Iron status was evaluated in four stages: 1) negative iron balance; 2) iron depletion; 3) iron deficient erythropoiesis; and 4) iron deficiency anemia according to Herbert (20). Hemoglobin concentrations were generally within the normal range (≥ 13 g/dL for males; ≥ 12 g/dL for females) (21), with the exception of 2 vegetarian female subjects (9.9 and 11.4 g/dL). Figure 1 shows the distribution of plasma iron, ferritin, TIBC, and transferrin saturation values of anemic vs. non-anemic subjects. Few subjects (4 vegetarian males; 5 vegetarian females, and 2 nonvegetarian females) had plasma iron concentrations less than 60 μg/dL, these were in an iron deficient erythropoiesis stage; only 1 vegetarian female was in an anemic stage with a plasma iron value less than 40 μg/dL (32 μg/dL). Nineteen subjects (1 vegetarian male, 1 nonvegetarian male, 13 vegetarian females, 4 nonvegetarian females) had plasma ferritin levels in an iron deficient erythropoiesis stage (10 - 20 ng/mL); while two female subjects (1 vegetarian, 1 nonvegetarian) had anemic ferritin levels (< 10 ng/mL). Five vegetarian and 1 nonvegetarian female subjects showed anemic TIBC levels > 410 μg/dL. Few subjects (3 vegetarian males, 6 vegetarian females, and 1 nonvegetarian female) had anemia with a value of transferrin saturation < 15%. In this study, a subject was considered to have iron deficient anemia if two or more abnormal values for iron status indices were observed. Six vegetarian females and 1 nonvegetarian female subjects were anemic because they had two or more abnormal biochemical indices of iron status.

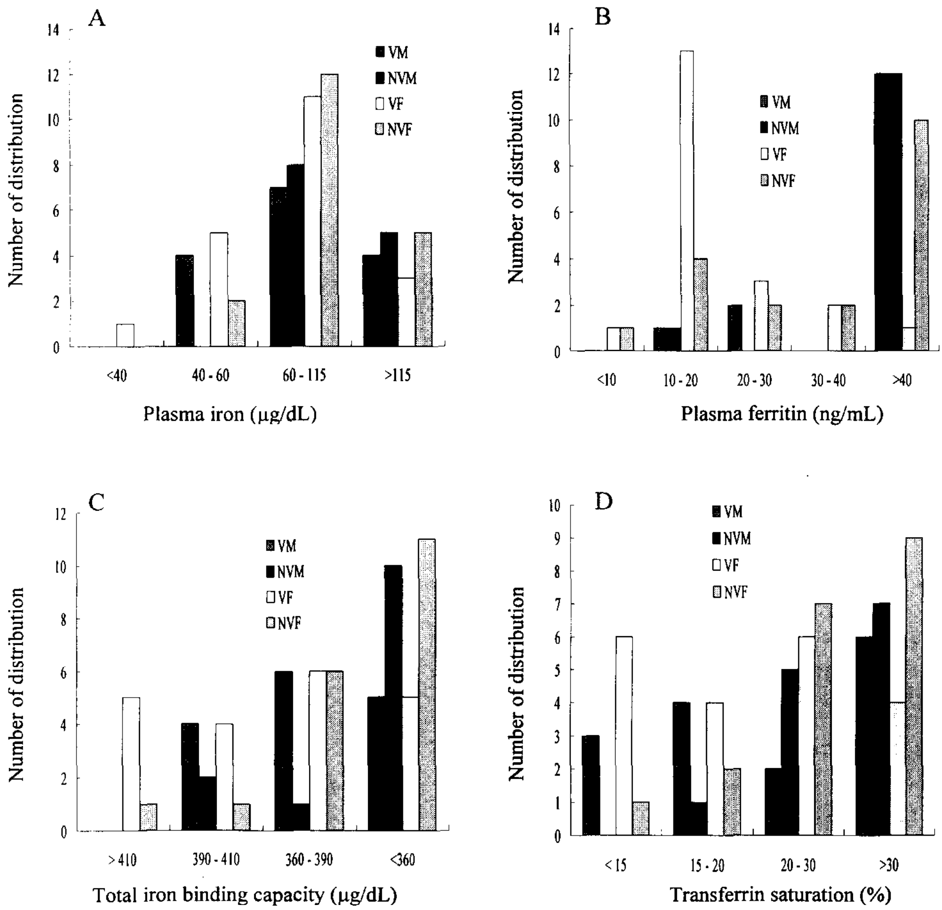

FIG 1. The distribution of plasma iron, ferritin, total iron binding capacity, and transferrin saturation values of anemic vs. non-anemic subjects (A. plasma iron; B. plasma ferritin; C. total iron binding capacity; D. transferrin saturation). Iron deficiency anemia is defined as: plasma iron < 40 μg/dL; plasma ferritin < 10 ng/mL; total iron binding capacity > 410 μg/dL; transferrin saturation < 15% (15,20,21).

There was no significant correlation between dietary intake (energy, protein, vitamin C, iron, calcium, and fiber) and iron status parameters (plasma iron, ferritin, TIBC, and transferrin saturation) in vegetarian and nonvegetarian female groups and the pooled nonvegetarian group (data not shown). However, vegetarian male subjects showed negative correlation between vitamin C intake and plasma iron or transferrin saturation, and the negative correlation was also found when vegetarian and female groups were pooled (Table 4). Reverse correlation was found in the pooled vegetarian group between iron intake and plasma iron or transferrin saturation (Table 4). Positive correlation was seen between energy intake and plasma ferritin concentration in the pooled vegetarian group; while the nonvegetarian male group showed negative correlation (Table 4). Reverse correlation between protein intake and transferrin saturation was only found in the nonvegetarian male group (Table 4). The pooled vegetarian group showed a negative correlation between fiber intake and plasma iron or transferrin saturation (Table 4).

TABLE 4

Significant Pearson Correlation Coefficients (r) Between Dietary Intake and Iron Status Parameters in Individual and Pooled Vegetarian and Nonvegetarian Groups

	Vegetarian			Nonvegetarian		
	Male (n=15)	Female (n=20)	Pooled (n=35)	Male (n=13)	Female (n=19)	Pooled (n=32)
Energy vs. plasma ferritin	NS*	NS	0.51#	- 0.78	NS	NS
Energy vs. TIBC**	NS	NS	NS	0.61	NS	NS
Energy vs. TS***	NS	NS	NS	- 0.64	NS	NS
Protein vs. TS***	NS	NS	NS	- 0.56	NS	NS
Vitamin C vs. plasma iron	- 0.54	NS	- 0.42	NS	NS	NS
Vitamin C vs. TIBC**	NS	NS	0.10	NS	NS	NS
Vitamin C vs. TS***	- 0.52	NS	- 0.38	NS	NS	NS
Iron vs. plasma iron	NS	NS	- 0.38	NS	NS	NS
Iron vs. TS***	NS	NS	- 0.38	NS	NS	NS
Fiber vs. plasma iron	NS	NS	- 0.35	NS	NS	NS
Fiber vs. TS***	NS	NS	- 0.35	NS	NS	NS

* NS; not significant

\# $p \leq 0.05$

** TIBC: Total iron binding capacity; ***TS: Transferrin saturation

DISCUSSION

Many studies have been performed to assess nutrient intakes and iron status in vegetarian and nonvegetarian subjects. Various dietary assessment methods have been used; however, 3-d dietary records are used the most. A 12-d dietary record was used in this study to assess nutrient intake in order to obtain more reliable data. Vegetarian female subjects had a significantly lower iron intake than nonvegetarians. Our findings contrast with that of Alexander et al. and others (2,22,23), who have also used 12-d diet records; and other studies (3,12), which have only used 7-d or 3-d diet records. Researchers have indicated that the iron intake of vegetarians was positively associated with energy (24) and protein (25) consumption. In this study, the relationship between iron and energy or protein intake was also observed in the two dietary groups (vegetarian and nonvegetarians). Although vegetarians had lower iron intake than nonvegetarians, their iron intake was 275% and 142% above the Taiwan RDNA (10 mg for men, 15 mg for women) for vegetarian males and females, respectively. Iron intake of both vegetarians and nonvegetarians was also higher than 16.9 mg/d which was estimated to be the average iron intake in the National Dietary Survey conducted in Taiwan in 1986-1988 (26).

Iron deficiency is a well recognized nutritional problem in developing countries. Iron deficiency anemia was detected in 10% of our population. None of the male subjects (vegetarian and nonvegetarian) were in iron deficient erythropoiesis nor an anemic stage. Occurrence and risk of iron deficiency are more prevalent in female groups (7 females), especially in vegetarian groups (6 vegetarian females). Although vegetarian females had a sufficient iron intake, even higher than the RDNA, some of them showed impaired iron status. The reason might be that of menstrual iron losses. Monthly menstrual blood loss in adult women is between 20 and 30 mL (27). This loss increases median daily iron requirements from a basal figure of approximately 0.8 mg to 1.36 mg, with 90^{th} and 95^{th} percentiles of 2.34 and 2.84 mg, respectively (28). Heavy blood loss (>80 mL/mo.) has been reported to occur in ~10% of women and frequently leads to anemia (29). We did not measure the menstrual losses in our female subjects, therefore, the effect of menstruation could not be documented.

Shaw et al. (4) reported that Taiwanese vegetarians (male and female) had an iron intake closer to or higher than the RDNA, yet both showed impaired status. The bioavailability of iron is probably the major determinant of the iron adequacy of a vegetarian diet. Monsen et al. (30) indicated that 18 mg daily iron intake was required to maintain iron balance in 95% of menstruating women with most meals of moderate availability. All subjects in our study had mean iron intake higher than 18 mg, however, 6 vegetarian and 1 nonvegetarian women had an anemia. The iron bioavailability is impaired in the vegetarians.

The vegetarians obtained most of their iron from grains, cereals, nuts, legumes and vegetables, which supplied exclusively nonheme iron. These nonheme sources have lower bioavailability than heme iron in animal products which are an important iron source of nonvegetarians. Thus, the actually amount of iron absorbed may be considerably lower. Calcium had been reported to inhibit nonheme iron absorption (31,32). However, Reddy and Cook (33) recently reported that calcium intake had no significant influence on nonheme iron absorption from a varied diet. We did not find any statistically significant correlations between dietary calcium and any iron status parameters in vegetarians. In addition, the majority of vegetarian subjects had calcium intakes below the Taiwan RDNA, especially in women (75%). Therefore, calcium may not be an important factor to impact iron bioavailability in our population. Vitamin C has a beneficial effect on the absorption of iron (8,9). Although vegetarian subjects had a vitamin C intake 2 times above the RDNA of 60 mg, the bioavailability of nonheme iron is substantially less than that of heme iron. Consumption of vitamin C rich food with iron containing foods is necessary for effective interaction. Hallberg et al. (6) indicated that the effect of vitamin C on increasing absolute iron absorption was greatest when no phytates were present in the meal and was smallest at the highest level of phytates. Therefore, the benefits of vitamin C might be compromised by separate consumption, heat susceptibility during cooking and dietary inhibitors of iron absorption (i.e., tannin, and phytates). An interesting finding is that iron and vitamin C intakes of vegetarian subjects showed negative correlation with plasma iron and transferrin saturation. Further research on the relationship between dietary intake and biochemical iron status is warranted.

In this study, subjects with anemia were within normal hemoglobin range, while only 2 anemic vegetarian females had hemoglobin level < 12 g/dL. Donovan and Gibson (34) also found a high prevalence of depleted iron stores as well as an insufficient supply of iron for normal hematopoiesis. Hemoglobin level is not low in either iron depletion or iron deficiency erythropoiesis; therefore, it can not be used alone to detect the iron deficiency. Plasma ferritin is considered as a sensitive index of iron storage (35) and is one of the most commonly deficient biochemical indices in vegetarians (14). However, only 1 vegetarian female among 7 anemic subjects had a plasma ferritin level less than 10 ng/mL. Six subjects (5 vegetarian and 1 nonvegetarian females) showed impaired total iron binding capacity and transferrin saturation level. All anemic subjects had impaired transferrin saturation levels, and 5 out of 7 anemic subjects had abnormal total iron binding capacity. The proportion of anemic subjects with low transferrin saturation was higher than those with low plasma ferritin levels, attributed to the abnormally high TIBC levels. This finding of the present study is similar to that of Donovan and Gibson. (34). Reasons for this are unclear. Because subjects with anemia were females, it might be due to the menstruation and hormonal changes not with lower iron intake. Our study shows that transferrin saturation status should be evaluated when anemia is determined.

In conclusion, vegetarian subjects had sufficient iron intake even higher than the RDNA. The bioavailability of iron was limited to maintaining iron balance and, therefore, showed impaired iron status, especially in women. A combination of iron indices is recommended to determine the iron status, and the level of transferrin saturation should be included.

ACKNOWLEDGEMENTS

This study was supported in part by grant NSC-86-2314-B-040-067-T, National Science Council, and CSMC 85-OM-B-019, Chung Shan Medical and Dental College, Taiwan, ROC. We thank to Dr. Madeleine E. Mitchell and Dr. Linda K. Messay for their critical review of our manuscript. We also express our sincere appreciation to the subjects for their participation in this study.

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Accepted for publication October 2, 1998.