Original Article

Iron status and dietary intake of Chinese pregnant women with anaemia in the third trimester

Aiguo Ma[1] MD, Xuecun Chen[2] MD, Mingci Zheng[3] PhD, Yu Wang[4] MD, Rongxian Xu[5] MD and Juesheng Li[1] MD

[1]*Institute of Human Nutrition, Qingdao Medical College, Qingdao University, China*
[2]*Institute of Nutrition and Food Hygiene, Chinese Academy of Preventive Medicine, Beijing, China*
[3]*Department of Pediatrics, Guilin Medical College, Guilin, China*
[4]*Department of Preventive Medicine, Lanzhou Medical College, Lanzhou, China*
[5]*Department of Preventive Medicine, Fujian Medical University, Fuzhou, China*

Anaemia in pregnancy is a major public health problem in China. Anaemia in pregnant women may be related to dietary intake of nutrients. To examine the relationship between iron status and dietary nutrients, a cross-sectional study in pregnant women was carried out. The intake of foods and food ingredients were surveyed by using 24-h dietary recall. Blood haemoglobin, haematocrit, serum iron, serum ferritin, transferrin and soluble transferrin receptor were measured in 1189 clinically normal pregnant women in the third trimester of pregnancy. The results showed that the average daily intake of rice and wheat was 504.2 g in the anaemia group and 468.6 g in the normal group. Carbohydrates accounted for 63.69% and 63.09% of energy in the anaemia and normal groups, respectively. Intake of fat was very low; 18.38% of energy in anaemia group and 19.23% of energy in normal group. Soybean intake was 109.4 g/day and 63.6 g/day in the anaemia and normal groups, respectively ($P < 0.001$). There were lower intakes of green vegetables (172.1 g/day) and fruits (154.9 g/day) in the anaemia group than in the normal group (246.2 g/day green vegetables ($P < 0.001$) and 196.4 g/day fruit ($P < 0.001$)). Intakes of retinol and ascorbic acid were much lower in the anaemia than in the normal group ($P < 0.001$). In the anaemia group, vitamin A intake was only 54.76% of the Chinese recommended daily allowance (RDA) and ascorbic acid intake was 53.35% of the Chinese RDA. Intake of total vitamin E was 14.55 mg/day in the anaemia group compared with 17.35 mg/day in the normal group ($P < 0.016$). Moreover, intake of iron in pregnant women with anaemia was slightly lower than that in the normal group. Comparison of iron status between the anaemia and normal groups found serum iron in women with anaemia at 0.89 μg/L, which was significantly lower than 1.09 μg/L in the normal group ($P < 0.001$). There were lower average values of ferritin (14.70 μg/L) and transferrin (3.34 g/L) in the anaemia group than in the normal group (20.40 μg/L ferritin ($P < 0.001$) and 3.44 g/L transferrin ($P < 0.001$)). Soluble transferrin receptor was significantly higher (32.90 nmol/L) in the anaemia than in the normal group (23.58 nmol/L; $P < 0.001$). The results of this study indicate that anaemia might be attributed to a low iron intake, a low intake of enhancers of iron absorption and a high intake of inhibitors of iron absorption from a traditional Chinese diet rich in grains.

Key words: anaemia, China, ferritin, iron, pregnancy, Qingdao, soluble transferrin receptor, vitamins.

Introduction

A deficiency of iron in the diet is the most common cause of nutritional anaemia. Several studies in humans and animals have shown that abnormalities of iron metabolism are associated with vitamin deficiencies and intake of inhibitors of iron absorption in foods.[1,2] The differing benefits of vegan and omnivorous diets have long been a topic of nutrition research. Numerous investigations have reported a lower iron status among vegetarians and vegans.[3–5] China is a country with a wide diversity of dietary habits, living environments and climates. Staple grains vary from rice to wheat to corn and the source of protein mainly comes from vegetables. High rates of anaemia or iron deficiency in pregnant women and children are still a major problem.[6] One report showed that the incidence of anaemia during pregnancy was 10–20%, even reaching 42.55% among pregnant women in the third trimester in Beijing, China.[7] Although the diagnosis of anaemia is fairly simple and the treatment inexpensive, the prevalence of anaemia remains high, even in developed towns, as well as in the general countryside and poverty-stricken areas of China. The populations studied vary considerably in their intake of dietary enhancers and inhibitors. The aims

Correspondence address: Professor Aiguo Ma, Institute of Human Nutrition, Qingdao Medical College, 38 Dengzhou Road, 266021, Qingdao, PR China.
Fax: +86 532381 2434
Email: maiguo@public.qd.sd.cn
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were to explore the relationship between iron status and dietary nutrients in Chinese pregnant women.

Subjects and methods

Subjects

The study involved the examination of 1189 clinically normal pregnant women aged 20–35 years in the third trimester of pregnancy. Subjects were enrolled from four centres: two rural areas and two developing towns of China. All subjects selected were geographically part of the larger population of China. Differences in variable diet, food supply, living habit, climate and socioeconomic status may exist between the areas. The stage of gestation and estimated date of delivery were calculated from the first day of the last menstruation and compared with results from the obstetric examination. Subjects included in the study were healthy pregnant women without abnormal bleeding, who refrained from smoking tobacco products or drinking alcoholic beverages. The study was carried out according to the ethical standards of the local authorities and informed consent was obtained from every subject.

Dietary survey and assessment

The intake of foods and food ingredients was surveyed by using 24-h dietary recall. Major nutrient intake in the diet was calculated by comparing the food intake with the Chinese Food Composition Table.[8]

Collection and analysis of blood

Two hundred and ninety of 1189 randomly selected subjects were questioned about food consumption and socioeconomic status. Venous blood samples (5 mL) and urine samples (10 mL) were taken from 1189 subjects on the same day as antenatal examination. The samples were stored on ice for transport to the laboratory. Haematocrit and haemoglobin concentration were measured and serum was separated from blood by centrifugation at $2000 \times g$ for 15 min at room temperature. Samples of serum were stored separately at – 80°C in the dark and then transported to a single centre for analysis of ferritin, serum iron, transferrin and soluble transferrin receptor (sTfR).

Serum sTfR was measured by enzyme immunoassay using a commercial kit (R&D Systems, Minneapolis, MN, USA). Haemoglobin concentration and haematocrit were measured by automatic biochem-analysers. A standard haemoglobincyanide solution was used for quality control of haemoglobin measurements. Measurements of serum ferritin were carried out by radioimmunoassay[9] described by the manufacturer (North Biological Technology Institute, Beijing, China). Transferrin was determined by a commercially available kit (Yadu Biotech, Shanghai, China). Serum iron was determined by atomic absorption spectrometer.

Statistical analysis

Significant differences were determined by independent samples *t*-test and by the χ^2 test. SPSS-9.0 statistical software (SPSS, Chicago, IL, USA) was used.

Results

Dietary patterns and food intake in pregnant women with anaemia were different from those in the normal group. Table 1 shows a typical Chinese traditional diet with staple grains. Intake of rice and wheat were 504.2 g in the anaemia group and 468.6 g in the normal group. Subjects in the anaemia group had a lower intake of heme food, such as meat ($P < 0.001$) and eggs ($P < 0.001$), than subjects in the normal group. The bean intake (bean curd) was higher in the anaemia group than in the normal group ($P < 0.01$). In contrast, there were lower intakes of green vegetables ($P < 0.001$) and fruits ($P < 0.001$) in women with anaemia than in the normal group.

Table 2 shows the daily dietary intake of 12 nutrients. The main source of energy was carbohydrates, which accounted for 63.69% and 63.09% of energy in the anaemia and normal groups, respectively. The intake of fat was very low, 18.38% in the anaemia and 19.23% in the normal group. Intakes of retinol and ascorbic acid were much lower in the anaemia group than in the normal group ($P < 0.001$, $P < 0.001$). In the anaemia group, vitamin A intake was only 54.76% of the Chinese recommended daily allowance (RDA; 1000 μg RE) and ascorbic acid intake was 53.35% of the Chinese RDA (80 mg). Intake of total vitamin E in the anaemia group was 14.55 mg/day, much lower than the 17.35 mg/day seen in the normal group ($P < 0.016$). Riboflavin was 53.89% and 51.67% of the Chinese RDA (1.8 mg) in the anaemia and normal groups, respectively. There was no significant

Table 1. Dietary patterns of pregnant women with anaemia and pregnant women without anaemia in China

Food (g)	Anaemia		Normal group		*P*-value
	No.	Mean ± SD	No.	Mean ± SD	
Rice	93	236.2 ± 95.9	120	213.6 ± 106.	0.109
Wheat	112	268.0 ± 166.5	133	255.0 ± 132.2	0.502
Meat	103	58.5 ± 38.6	120	97.5 ± 48.7	0.000
Eggs	68	56.7 ± 26.0	68	86.3 ± 69.8	0.002
Milk	48	245.2 ± 116.2	52	273.5 ± 121.1	0.237
Beans	70	109.4 ± 42.2	62	63.6 ± 31.9	0.000
Seafoods	55	104.4 ± 66.1	64	112.6 ± 77.4	0.539
Vegetables	112	172.1 ± 74.1	140	246.2 ± 68.7	0.000
Fruits	109	154.9 ± 62.2	137	196.4 ± 82.6	0.000

difference between the two groups. There was a low intake of calcium in both the anaemic and normal groups. Iron intake was close to the Chinese RDA (28 mg/day) in both groups.[10] Intake of iron by pregnant women with anaemia was slightly lower than that in the normal group.

There was a relationship between iron status, and transferrin, ferritin and serum iron levels (Table 3). Serum iron in anaemia was 0.89 μg/L; significantly lower than 1.09 μg/L in the normal group. There were lower average values of haematocrit, ferritin and transferrin in the anaemia group. It was found that the mean level of sTfR was much higher in the anaemia group (32.90 nmol/L) than in the normal group (23.58 nmol/L), suggesting that anaemia might be attributed to iron deficiency in pregnant women.

Discussion

The subjects in this study were chosen for their range of haemoglobin levels. They provide an opportunity to compare the influence of dietary patterns and nutrient intake on the iron status of pregnant women. Dietary sources of macronutrients and micronutrients reflected the dietary patterns of pregnant women with little meat or dairy intake and with most of their calories and protein coming from plant sources (principally grains). The average iron intake of 23.52 mg/day in anaemic women and 25.93 mg/day were almost close to the Chinese RDA of 28 mg/day and the USA RDA of 30 mg/day for pregnant women.[11] This means that the intake of dietary iron was not low. Indicators related to iron status detected in this study showed a higher ratio of iron deficiency in pregnant women with anaemia than in the normal group. However, the higher intake of iron and iron deficient anaemia might be due to the typical Chinese diet of higher grain intake and less animal foods. Some authors have reported a correlation between iron intake, usually as heme iron, and iron status.[12,13] However, others have failed to demonstrate an association between iron status and intake of dietary iron due to variability in iron absorption and blood loss.[14] While it remains axiomatic that iron status is dependent on iron intake, a number of modifying factors must be considered. One of these is the difference in bioavailability of heme and non-heme iron. Since the more bioavailable heme iron is present only in meat products and is therefore not present in vegetarian diets, it is consistent that vegetarians would have lower iron status. It has been shown that vegetarians have lower serum ferritin[15] and that meat intake specifically increases serum ferritin.[16] In this study, the intake of the heme food, such as meat, was very low in anaemic pregnant women so that iron absorption and utilization in the body were limited.

Table 2. Daily intakes of food nutrients of subjects in China†

Nutrient (mg)	Anaemia (n = 127)	Normal group (n = 163)	P-value
Energy (kcal)	2168.10 ± 767.7	2258.20 ± 768.10	0.162
Protein (g)	96.70 ± 40.80	98.10 ± 41.50	0.702
Fat (g)	43.90 ± 37.30	47.70 ± 35.80	0.225
Carbohydrates (g)	342.20 ± 129.30	352.80 ± 126.40	0.318
Retinol equivalents (μg)	547.60 ± 512.40	832.90 ± 1097.30	0.000
Vitamin B_1	1.79 ± 0.76	1.77 ± 0.79	0.720
Vitamin B_2	0.97 ± 0.60	0.93 ± 0.64	0.399
Niacin	16.29 ± 6.54	15.58 ± 6.73	0.204
Vitamin C	42.68 ± 28.42	52.88 ± 39.98	0.000
Total vitamin E	14.55 ± 12.13	17.35 ± 15.72	0.016
Calcium	609.10 ± 323.40	634.1 ± 345.68	0.375
Iron	23.52 ± 8.89	25.93 ± 12.17	0.006
Zinc	19.83 ± 10.02	18.39 ± 8.49	0.062
Selenium (μg)	59.27 ± 38.03	53.80 ± 36.07	0.078

† Mean ± SD.

Table 3. Indicators of iron status of pregnant women with anaemia and normal group in China

Indicator	Anaemia		Normal group		Abnormal range
	No.	Mean ± SD	No.	Mean ± SD	
Haematocrit (%)	536	30.83 ± 4.86	525	36.66 ± 4.84	<33
Serum iron (μg/mL)	509	0.89 ± 0.50	521	1.09 ± 0.70	<0.5
Ferritin (μg/L)	536	14.70 ± 10.27	589	20.39 ± 17.94	<12
Transferrin (g/L)	576	3.341 ± 0.426	609	3.44 ± 0.45	<2.1
sTfR (nmol/L)	88	32.90 ± 18.65	68	23.58 ± 7.36	>8.0

All indicators were significantly different between the anaemic and normal groups (P = 0.000). sTfR, soluble transferrin receptor.

Serum iron generally has a rather high coefficient of variation compared to other measures of iron status and to other blood chemistry measurements.[17] In this study, serum iron also was correlated to other iron status measurements and determinants of iron status. Ferritin appears to be an effective measure of iron deficiency when compared to bone marrow iron levels.[18] Others have observed a reduction of serum ferritin in iron deficiency anaemia.[19] The progression of iron deficiency may be followed by the changing pattern of blood markers. As liver iron stores are depleted, serum ferritin decreases. Liver stores are considered to be depleted when serum levels are below about 20 μg/L.[14] If deficiency continues to progress, then eventually haemoglobin levels start to fall. Transferrin receptor, a disulphide-linked transmembrane glycoprotein, plays an essential role in cellular iron uptake, especially in bone marrow.[20] Although it is a cell membrane protein, small quantities circulate in blood and are called sTfR. Recent work by different investigators has suggested that sTfR is a sensitive indicator of tissue iron deficiency.[21–23] Blood concentrations are increased several fold in subjects with iron deficiency, whereas they remain within the normal range in those with iron overload. Serum sTfR concentration is not affected by pregnancy unless the subject is also iron deficient.[18] Unlike serum ferritin, sTfR is not affected by infection and inflammation and it may distinguish anaemia due to chronic disease from that due to iron deficiency.[24,25] In this study, the average values of sTfR were much higher in the anaemia group than in the normal group. The results also suggested that most pregnant women with anaemia suffer from iron deficiency and pregnant women should eat food rich in iron, such as meat or other animal food.

A number of effectors of iron absorption have been found in this study. These include low vitamin C intake and high grain intake rich in fibres and polyphenols.[16,26,27] A higher intake of soy products has been suggested as an inhibitor of iron absorption in the women with anaemia. In addition, such diets include abundant amounts of cereals, legumes and vegetable components, such as phytate, fibres and soybean protein, which are inhibitory to non-heme iron absorption.[28–30] Most of the subjects selected in this study were from four centres, which were developing or poor areas of the countryside. Therefore, one of the nutritional problems related to nutrient adequacy in their diets is iron deficiency, where soybean products are often substituted for animal products. Several investigations have demonstrated that the percentage of iron absorption from soybean products was low in humans[31] and that inclusion of soybean products in the diet inhibits iron absorption.[32] Nevertheless, no subjects in this study took any supplement containing iron. This may imply that the general population in the areas studied was not aware of the risk of iron deficiency. Unlike Western societies, food in China is not routinely fortified with iron.

Because the period of investigation was in winter, from September to April, the number of green vegetables in the subjects' diets was very low. Green vegetables are available from greenhouses but at much higher prices and most subjects could not afford them. Comparatively, the subjects ate mainly apples, which supply little vitamin C and riboflavins. In the Chinese general diet, vegetables are commonly stir-fried and the benefit of vitamin C is compromised by heat susceptibility. Fruit or fresh fruits are seldom eaten with a meal. Therefore, serum levels of vitamin C were low in the anaemia and normal groups. Intakes of retinol and carotene were lower in the anaemia group than in the normal group (Table 2). This may be related to low intake of meat and green vegetables. The enhancing effect of ascorbic acid on the absorption of non-heme iron has been observed repeatedly.[33] Two studies suggested supplementation of vitamin C may be helpful, but the effect has not been validated. Iron supplementation is expected to be more effective.[32,34] Although vitamin C enhances absorption of non-heme iron, simultaneous occurrence of both vitamin C and iron in the gut is necessary for effective interaction.[35] Vitamin A and carotene can improve non-heme iron absorption. Deficiency of this vitamin results in anaemia in humans and animals that is reversed only by vitamin A supplementation.[36] β-Carotene is the most abundant provitamin A in food. Approximately 10–15% of total β-carotene consumed is absorbed in the gastrointestinal tract and is partially converted into vitamin A within the intestinal wall. β-Carotene accumulation is not toxic, and is considered to be a safe source of vitamin A.

Iron status and iron absorption were related to nutrients in diets. Because the intake of enhancers of iron absorption, such as vitamin C, retinol and carotene, is very low, the prevalence of anaemia is still common especially in pregnant women, children and old people. Therefore, further studies examining ways of increasing the intake of non-heme food or supplementation of vitamins and iron should be carried out to improve the iron status of Chinese pregnant women.

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