Anemia and Deficiencies of Folate and Vitamin B-6 Are Common and Vary with Season in Chinese Women of Childbearing Age

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ABSTRACT  Little is known about the micronutrient status of Chinese women of childbearing age. We assessed nonfasting plasma concentrations of folic acid, vitamin B-12, vitamin B-6 (as pyridoxal-5'-phosphate), hemoglobin (Hb), ferritin and transferrin receptor (TfR) in 563 nonpregnant textile workers aged 21–34 y from Anqing, China. All women had obtained permission to become pregnant and were participating in a prospective study of pregnancy outcomes. Mean (SD) plasma concentrations were 9.7 (4.1) nmol/L folic acid, 367 (128) pmol/L vitamin B-12, 40.2 (15.8) nmol/L vitamin B-6, 108 (12.9) g/L Hb, 42.6 (34.2) μg/L ferritin and 5.2 (2.7) mg/L TfR. Twenty-three percent of women had biochemical evidence of folic acid deficiency, 26% were deficient in vitamin B-6 and 10% had low vitamin B-12. Overall, 44% of women were deficient in at least one B vitamin. Although anemia (Hb < 120 g/L) was detected in 80% of women, only 17% had depleted iron stores (ferritin < 12 μg/L); 11% had elevated TfR concentrations. Distinct seasonal trends were observed in the prevalence of moderate anemia (Hb < 100 g/L) and deficiencies of folic acid and vitamin B-6, with significantly lower concentrations of folate and Hb occurring in summer and lower concentrations of vitamin B-6 occurring in winter and spring than in other seasons. We conclude that deficiencies of folic acid, vitamin B-6 and iron were relatively common in this sample of Chinese women of childbearing age and were contributing to the high prevalence of anemia. Without appropriate supplementation, these deficiencies could jeopardize the women’s health and increase their risk of adverse pregnancy outcomes.


KEY WORDS: • China • women • folic acid • vitamin B-12 • vitamin B-6 • iron

Little is known about the micronutrient status of women in China. Most Chinese nutrition surveys have involved men and have assessed dietary intake, usually with respect to energy and protein. Few studies have measured biochemical indicators of micronutrient status, particularly among women of childbearing age. According to U.S. data, however, the highest prevalence of certain micronutrient deficiencies occurs among young women aged 20–44 y (Life Sciences Research Office 1984), and similar findings have been reported for women in developing countries (Hercberg and Galan 1992). The limited data that are available from China suggest that deficiencies of iron (Li et al. 1993, Zhou et al. 1998), folic acid (An and Xiu-qing 1986) and other B vitamins (Zhan et al. 1997) may be relatively common among young Chinese women.

The recognition of micronutrient deficiencies in women of reproductive age is important not only because nutritional status affects the woman’s health and productivity but also because deficiencies are associated with adverse pregnancy outcomes. Poor periconceptional folic acid status increases the risk of neural tube defects (NTD3) (Creizel and Dudas 1992, Mills et al. 1995, Steegers-Theunissen et al. 1994), and other evidence indicates that vitamin B-12 status also may influence NTD risk, independent of folate status (Kirke et al. 1993, Steen et al. 1998). Folate deficiency during pregnancy has been associated with low birth weight (LBW) and preterm delivery (Baumslag et al. 1970, Scholl et al. 1996), and prenatal vitamin B-6 status may influence birth weight as well (Kubler 1981). Poor B vitamin status also has been linked to hyperhomocysteinemia, which is associated with an increased risk of NTD (Mills et al. 1995, Molloy et al. 1998), preeclampsia (Leeda et al. 1998, Rajkovic et al. 1997) and spontaneous abortion (Steegers-Theunissen et al. 1992, Wouters et al. 1993).

Iron deficiency remains the most common nutrient deficiency worldwide, with women of childbearing age among those at the greatest risk (DeMaeyer and Adiels-Tegman 1985). Iron deficiency impairs immune function (IOM 1990) and was associated with reduced work output among women cotton mill workers in Beijing, China (Li et al. 1994). Recent evidence indicates that iron deficiency during pregnancy negatively affects fetal growth (Singla et al. 1997) and increases...
the risk of infant iron deficiency (Kilbride et al. 1999, Preziosi et al. 1997), which is associated with lower Apgar scores (Preziosi et al. 1997) and potentially irreversible delays in cognitive and psychomotor development (Lozoff et al. 1996). The identification of iron deficiency can be complicated by physiologic changes that perturb typical measures of iron status. For instance, although plasma ferritin concentration is the most sensitive indicator of iron deficiency in healthy persons (Cook and Skikne 1989), infections and other inflammatory processes that trigger an acute-phase response can artificially elevate ferritin concentrations. Previous studies indicate that the exposure of textile workers to cotton dust initiates both acute and chronic lung inflammation (Li et al. 1995, Rylander 1987), which could spciously elevate ferritin concentrations, thereby complicating estimates of iron deficiency in textile workers. Recently, transferrin receptor (TfR) concentration was identified as a useful and stable measure of iron status, reflecting tissue iron availability while remaining unaffected by infection (Ahuwalia 1998). The determination of both ferritin and TfR may provide a more sensitive and reliable measurement of iron status in some groups, including textile workers. Although micronutrient deficiencies in reproductive-age women jeopardize both their health and that of their offspring, intervention trials indicate that supplementation improves nutritional status (Li et al. 1994, Ubbink et al. 1994) and reduces the reproductive risks associated with deficiency (Baumslag et al. 1970, Berry et al. 1999, Czeizel and Dudas 1992, Medical Research Council Vitamin Study Research Group 1991). In 1992, the U.S. Public Health Service advised women who were pregnant or were capable of becoming pregnant to consume at least 400 μg of folic acid/d (MMWR 1992). No data are available on the prevalence of routine periconceptional vitamin and mineral supplementation in China. However, cereal grains in China are not fortified with folic acid, and a recent folic acid intervention study in China found that 40–48% of women who had been asked to purchase and consume folate supplements in the perinatal period did not comply (Berry et al. 1999). Even in large urban areas such as Beijing, where antenatal care is widely available and prenatal supplements are routinely recommended, supplementation most likely begins after pregnancy has been clinically established, usually around weeks 8–10, which is too late to prevent adverse pregnancy events that occur earlier in gestation, such as spontaneous abortion or certain birth defects. Thus, suboptimal micronutrient status in young Chinese women could be an important determinant of adverse pregnancy outcomes that would be amenable to intervention.

The present study in Chinese women of childbearing age was designed to address the following questions: 1) How prevalent and severe are deficiencies of B vitamins and iron in this population? 2) Does the prevalence of these deficiencies vary by season? 3) What is the relation between anemia and plasma concentrations of ferritin and TfR? 4) What is the relation between anemia and B vitamin deficiencies?

SUBJECTS AND METHODS

Subjects. The current assessment of nutritional status was conducted in conjunction with an on-going prospective study of the effects of rotating shift work on reproductive outcomes among female textile workers in Anqing, China. Anqing is located ∼200 km west of Shanghai. All employees of the textile mills and their families receive health care, including prenatal, delivery and postnatal care, in the nearby hospital. For the present study, eligible subjects were the 563 women enrolled in the shift work study between August 1996 and December 1998. All women were married and between 20 and 34 y of age and had never smoked. In addition, eligible women had obtained permission to have a child and were attempting to become pregnant during the course of the prospective study. Women were excluded if they were pregnant at the initial interview, had tried unsuccessfully to get pregnant for at least 1 y, were current or former smokers or planned to quit smoking, or worked offshore of Anqing in the coming year. Although we originally intended to evaluate the effects of work shift on nutritional status, only 39 women enrolled during this period worked rotating shifts, so data for all types of shifts were pooled for analyses. The Human Investigations Review Committees at the Harvard School of Public Health and Beijing Medical University approved all study procedures, and informed consent was obtained from each woman.

Measurements. At enrollment, height and body weight in light clothing were measured to the nearest 0.1 kg and 0.1 cm, respectively, with a beam weighing scale and measuring system. At that time, interviewers administered a previously validated questionnaire to the women and their husbands to collect baseline information on socio-demographic, environmental and personal attributes that might be related to shift work and reproductive outcomes. Included among these variables were education level, menstrual characteristics (cycle length and bleeding days/cycle), use of contraceptives or vitamin and/or mineral supplements and current intake of alcohol.

Preexisting nonfasting blood samples were used for this project. They were obtained from women before the initial interview via venipuncture into 10-ml, metal-free EDTA-treated tubes. A small aliquot of whole blood was used to determine hemoglobin (Hb) concentration. The remaining blood was centrifuged, and plasma was obtained and stored at –20°C until shipped on dry ice to the Harvard School of Public Health, where it was stored at –70°C before nutritional analyses. Frozen samples were transported to the U.S. Department of Agriculture Human Nutrition Research Center on Aging at Tufts University, Boston, MA, where plasma concentrations of ferritin, TfR, folate acid and vitamins B-6 and B-12 were measured.

Plasma concentrations were determined in whole blood according to an automated colorimetric procedure. Plasma folate and vitamin B-12 concentrations were determined with a radioimmunoassay method using a commercially available kit from BioRad Diagnostics Group (Hercules, CA). Plasma vitamin B-6 (as pyridoxal-5'-phosphate) was measured according to the tyrosine decarboxylase apoenzyme method (Shin et al. 1983). Vitamin measurements were completed in four batches over an 11-mo period, with 63–282 samples in each batch. Typical coefficients of variation for in-house control plasma samples were 5.0–8.3% for folate, 5.3–7.4% for vitamin B-12 and 3.1–5.8% for vitamin B-6. Plasma ferritin and TfR concentrations were determined in a subset of 499 women for whom adequate plasma samples were available with the use of enzyme immunoassays kits from Ramco Laboratories (Houston, TX). These measurements were made in three batches during a 13-mo period, with 100–282 samples in each batch. Mean intra-assay and interassay variabilities were 4.2 and 6.0% for TfR and 6.7 and 7.7% for ferritin, respectively.

Statistical analysis. We used SAS statistical software for Windows, version 6.12 (SAS Institute 1989) for all analyses. Summary statistics were calculated and used to describe Hb and plasma concentrations of folic acid, vitamin B-12, vitamin B-6, ferritin and TfR. Mean (arithmetic) plasma vitamin concentrations were compared with published reference values to determine the proportion of women with deficiency. Below normal Hb concentration was defined as <120 g/L, which is based on World Health Organization recommendations (World Health Organization 1968) for nonpregnant women. Below-normal concentrations for other nutritional variables were defined as <12 μg/L for ferritin (DeMaeyer 1989), >8.3 μg/L for TfR (Yeung et al. 1998), <0.8 nmol/L (3 ng/mL) for folic acid (Herbert and Das 1994), <30 nmol/L for pyridoxal-5'-phosphate (Leklem 1994) and <221 pmol/L (300 pg/mL) for vitamin B-12 (Koehler et al. 1996).

To determine whether micronutrient status was related to age, body mass index (BMI), education, menstrual characteristics or the use of contraceptives, we compared mean micronutrient concentrations across categories of these variables using the General Linear Models (GLM) procedure of SAS Institute and compared the proportion of women with abnormal values across categories using χ² analyses (Selvin 1996). To determine whether micronutrient status
TABLE 1

Characteristics of Chinese women in the study

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n</th>
<th>25.0 ± 1.51</th>
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<th>49.2 ± 5.91</th>
<th>19.8 ± 2.11</th>
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<td></td>
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<td>Weight, kg</td>
<td>562</td>
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<td>Body mass index, kg/m²</td>
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<td>97.7</td>
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<td>Multivitamin and/or B vitamins</td>
<td>4</td>
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<td>Vitamin C, E or A</td>
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<td>1.6</td>
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<td>Current use of alcohol</td>
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<td>0.4</td>
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</table>

*1 Means ± sd.

High prevalence of micronutrient deficiencies and anemia. Although mean folic acid and vitamin B-6 concentrations were within the normal range, deficiencies of these vitamins were observed in 23 and 26% of women, respectively (Table 2). Ten percent of women had combined deficiencies of folic acid and vitamin B-6, and 39% were deficient in either folic or vitamin B-6. Low plasma concentrations of vitamin B-12 were observed in 10% of women. Overall, 44% of women were deficient in at least one B vitamin, although <2% were deficient in all three. The mean concentration of folic acid was significantly lower in women in the lowest BMI quintile (≤18.02 kg/m²) than in those in the upper four quintiles (8.7 ± 3.4 versus 10.0 ± 4.2 nmol/L, P = 0.001). In addition, the prevalence of folate deficiency decreased significantly across BMI quintiles from 30% in the lowest quintile to 17% in the highest quintile (P for trend = 0.02). The prevalence of vitamin B-12 deficiency, however, increased across BMI quintiles from 5% in the lowest quintile to 19% in the highest (P for trend = 0.0002). Vitamin status was unrelated to age, education, menstrual characteristics or contraceptive use.

Among the 557 women for whom Hb concentration was available, 80% were anemic, with Hb below the established World Health Organization cutoff value of 120 g/L (Table 2). As shown in the distribution of Hb concentration (Fig. 1), nearly 60% of women had an Hb concentration of 100–119 g/L, and 20% had <100 g/L; only 5% had <90 g/L. Plasma ferritin and TfR concentrations were determined in a subset of 499 women for whom adequate plasma samples were available. Of these, 17% had a ferritin concentration of <12 µg/L, indicating iron depletion (Table 2), and an additional 19% had a ferritin concentration of 12–24 µg/L, indicative of low but not yet depleted stores; 11% of women had elevated TfR. Overall, 22% of women had either low ferritin or elevated TfR. Mean TfR concentration was significantly higher among women with depleted iron stores than among women with ferritin in the highest quintile (P = 0.001). In addition, the prevalence of TfR deficiency increased across BMI quintiles from 6% in the lowest quintile to 10% in the highest (P for trend = 0.0002). Vitamin status was unrelated to age, BMI, education, contraceptive use, menstrual cycle length or number of bleeding days per cycle and either mean concentrations or percentage of Chinese women with abnormal values

TABLE 2

B Vitamins, hemoglobin, ferritin and transferrin receptor (TfR) concentrations and percentage of Chinese women with abnormal values

<table>
<thead>
<tr>
<th>Variable</th>
<th>n1</th>
<th>Means ± sd</th>
<th>Median</th>
<th>Abnormal2</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folic acid, nmol/L</td>
<td>563</td>
<td>9.7 ± 4.1</td>
<td>9.1</td>
<td>23.1</td>
<td>9.8</td>
</tr>
<tr>
<td>Vitamin B-12, pmol/L</td>
<td>563</td>
<td>367 ± 128</td>
<td>350</td>
<td>98.4</td>
<td>25.6</td>
</tr>
<tr>
<td>Vitamin B-6, nmol/L3</td>
<td>563</td>
<td>40.2 ± 15.8</td>
<td>38.4</td>
<td></td>
<td>80.1</td>
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<tr>
<td>Hemoglobin, g/L</td>
<td>557</td>
<td>108 ± 12.9</td>
<td>105</td>
<td>100</td>
<td>16.8</td>
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<tr>
<td>Ferritin, µg/L</td>
<td>499</td>
<td>42.6 ± 34.2</td>
<td>36</td>
<td></td>
<td>6.8</td>
</tr>
<tr>
<td>TfR, mg/L</td>
<td>499</td>
<td>5.2 ± 2.7</td>
<td>4.6</td>
<td>10.6</td>
<td>8.3</td>
</tr>
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</table>

*1 Sample size varies from 563 due to missing values (hemoglobin) or insufficient plasma for analyses (ferritin and TfR).

2 Abnormal is defined as folic acid <6.8 nmol/L, vitamin B-12 <221 pmol/L, vitamin B-6 <30 nmol/L, hemoglobin <120 g/L, ferritin <12 µg/L and TfR >8.3 mg/L.

3 As pyridoxal-5'-phosphate.
of single or combined B-vitamin deficiencies, nearly 17% had B-6 deficiency occurred in anemic women had elevated TfR. Spring compared with only 15% of women in fall ($P < 0.05$). The percentage decreased across Hb strata, with the prevalence of vitamin B-6 deficiency, for instance, nearly 250% greater among women in the lowest Hb group than among nonanemic women ($P < 0.0001$, Mantel-Haenszel).

**Relation between micronutrient deficiencies and anemia.** Mean folic acid and Hb concentrations were significantly lower in summer than in the other seasons, whereas mean vitamin B-6 concentration was lower in winter and spring than in summer and fall (Table 4). No seasonal variations were observed in plasma concentrations of vitamin B-12, ferritin or TfR.

Distinct seasonal trends also were observed in the prevalence of anemia and deficiencies of folic acid and vitamin B-6 (Fig. 2). Folate deficiency was much more common in summer than in the other seasons (42% versus $<20%$, $P = 0.001$), and the prevalence of moderate anemia (Hb $<100$ g/L) followed the same seasonal pattern as folate deficiency, with twice as many moderately anemic women observed in summer as in winter (31% versus 15%, $P = 0.01$). The percentage of women with mild anemia (Hb 100–120 g/L) remained fairly constant across the seasons at $\sim 60%$ (data not shown). Vitamin B-6 deficiency occurred in $\sim 35%$ of women in winter and spring compared with only 15% of women in fall ($P = 0.001$).

**Seasonal variations in micronutrient deficiencies and anemia.** Mean folic acid and Hb concentrations were significantly lower in summer than in the other seasons, whereas mean vitamin B-6 concentration was lower in winter and spring than in summer and fall (Table 4). No seasonal variations were observed in plasma concentrations of vitamin B-12, ferritin or TfR.

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**Relation between micronutrient deficiencies and anemia.** We compared nutritional status across three strata of Hb concentration: $<100$, 100–119 and $\geq 120$ g/L (Table 5). Mean concentrations of all three vitamins were significantly lower among women with Hb of $<100$ g/L than among nonanemic women. Moreover, the prevalence of vitamin deficiencies decreased across Hb strata, with the prevalence of vitamin B-6 deficiency, for instance, nearly 250% greater among women in the lowest Hb group than among nonanemic women. Among women with Hb of $<100$ g/L, 54% were deficient in one or more vitamins compared with 31% of nonanemic women ($P = 0.002$). Although the prevalence of iron depletion (ferritin $<12 \mu g/L$) was 275% greater among women in the lowest Hb group than among nonanemic women, only 18% of all anemic women and 23% of women with Hb of $<100$ g/L had depleted iron stores, and only 12% of anemic women had elevated TfR.

**DISCUSSION**

In the present study, 44% of Chinese women had evidence of single or combined B-vitamin deficiencies, nearly 17% had depleted iron stores and 80% were anemic. Because our subjects had already obtained the government permission that is required in China before having a child, most will attempt to become pregnant during subsequent months. Unless periconceptional supplementation is initiated, many women will enter pregnancy with severely compromised micronutrient status, which will likely deteriorate further in response to the physiologic demands of gestation, thereby increasing their risk of adverse pregnancy events.

We found strong evidence that the prevalence of moderate anemia and deficiencies of both folate and vitamin B-6 varies according to season. Zheng et al. (1989) also reported seasonal variations in folate status among subjects in Linxian, China, with lower red cell folate observed between April and August compared with September through March, which is consistent with our finding of lower plasma folate during summer. To our knowledge, ours is the first report of seasonal variation in vitamin B-6 status from China. Understanding seasonal variations in nutritional status is particularly important in women of childbearing age because some evidence suggests that perinatal outcomes, including perinatal death, also vary by season (Zhang et al. 1991).

The high prevalence of deficiencies of folic acid or vitamin B-12 (30%) among women who may be attempting to become pregnant poses particular reproductive risks given recent findings that relate poor periconceptional folate (Czeizel and Dudas 1992, Mills et al. 1995) and vitamin B-12 (Kirke et al. 1993, Steen et al. 1998) status to the occurrence of NTD and other birth defects (Shaw et al. 1995). Reports indicate that NTD occur more frequently in rural areas (Hu et al. 1996, Liang et al. 1987, Wang et al. 1996) and Northern provinces (Berry et al. 1999, Moore et al. 1997) of China than in Western countries, and there is evidence that poor B vitamin status may be involved. In a study of 195 urban and 216 rural women, Zhan et al. (1997) reported a correlation between measures of folate and vitamin B-12 status and the occurrence of NTD in rural China. Furthermore, a recent folic acid supplementation trial among nearly 250,000 Chinese women reported that periconceptional intake of 400 μg of folic acid/d reduced the risk of NTD by as much as 85% in Northern areas and 40% in Southern regions (Berry et al. 1999).

In addition to birth defects, however, which are relatively rare events, maternal B vitamin deficiencies may contribute to more common adverse pregnancy complications, such as spontaneous abortion (Giles 1966, Hibbard 1964, Wouters et al. 2001).
1993), preeclampsia (Brophy and Sibbieri 1975), preterm birth and LBW (Hibbard 1975, Kubler 1981, Scholl et al. 1996), and can lead to elevated homocysteine concentrations, which have been linked to preeclampsia (Rajkovic et al. 1997) and spontaneous abortion (Wouters et al. 1993). The high prevalence of B vitamin deficiencies that we observed may increase the risk of adverse pregnancy outcomes. In 1990, the proportion of Chinese infants with LBW was estimated at 5–9.9% (World Health Organization 1992). Zhang et al. (1991) reported that from 1986 to 1987, the perinatal mortality rates in Shanghai were 13 and 15 times higher among LBW and preterm infants, respectively, than among infants of normal weight and gestational age. Correction of maternal vitamin deficiencies through supplementation could provide an easy and inexpensive means of reducing perinatal deaths.

In the present study, 17% of women had ferritin concentrations of $12 \text{ mg/L}$, and an additional 19% had ferritin concentrations of $12–24 \text{ mg/L}$, reflecting low but not yet depleted iron stores. Although these findings suggest that nearly 40% of women had some degree of iron depletion, they may actually underestimate the true prevalence of iron deficiency. Ferritin concentration is pathologically elevated in response to acute and chronic inflammation (Blake et al. 1981, Kuvibidila et al. 1994), and Li et al. (1995) reported that exposure to cotton dust increased airway inflammation in cotton mill workers in Beijing. Similar increases in inflammatory markers among textile workers have been reported by others (Keman et al. 1998, Rylander 1987), and it is possible that the women in our study had artificially elevated ferritin concentrations due to an inflammatory response related to textile work. An independent measure of inflammation, such as C-reactive protein, would be necessary to confirm this suspicion.

Even if we assume that only 17% of our subjects have iron deficiency, without supplemental iron their iron status is likely to deteriorate further, particularly because most will become pregnant over subsequent months (IOM 1990). In a study of 221 pregnant women in Taipei, Taiwan, Ho et al. (1987) found that 10% of previously nonanemic, unsupplemented women developed frank iron deficiency anemia and that 52% developed some degree of iron deficiency during pregnancy. Poor maternal iron status during pregnancy is associated with reduced infant length and Apgar scores (Preziosi et al. 1997), lower birth weight and mid-arm circumference (Singla et al. 1997) and iron deficiency during infancy (Kilbride et al. 1999), which is associated with long-term developmental disadvantages (Lozoff et al. 1991).

### Table 4

<table>
<thead>
<tr>
<th>Variable</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folic acid, nmol/L</td>
<td>n (562)²</td>
<td>127</td>
<td>112</td>
<td>113</td>
</tr>
<tr>
<td>Means (95% CI)³,⁴</td>
<td>10.2 (9.5–10.9)ᵃ</td>
<td>10.7 (10.0–11.3)ᵃ</td>
<td>7.9 (7.2–8.6)ᵇ</td>
<td>9.8 (9.3–10.4)ᵃ</td>
</tr>
<tr>
<td>Vitamin B-6, nmol/L⁵</td>
<td>n (562)</td>
<td>127</td>
<td>112</td>
<td>113</td>
</tr>
<tr>
<td>Means (95% CI)</td>
<td>36.0 (32.4–39.7)ᵇ</td>
<td>36.0 (32.1–39.9)ᵇ</td>
<td>46.5 (42.7–50.4)ᵃ</td>
<td>43.2 (40.4–46.0)ᵃ</td>
</tr>
<tr>
<td>Vitamin B-12, pmol/L</td>
<td>n (562)</td>
<td>127</td>
<td>112</td>
<td>113</td>
</tr>
<tr>
<td>Means (95% CI)</td>
<td>359 (336–381)ᵃ</td>
<td>376 (353–400)ᵃ</td>
<td>357 (333–381)ᵃ</td>
<td>375 (357–392)ᵃ</td>
</tr>
<tr>
<td>Hemoglobin, g/L</td>
<td>n (557)</td>
<td>126</td>
<td>112</td>
<td>110</td>
</tr>
<tr>
<td>Means (95% CI)</td>
<td>110.0 (107.8–112.3)ᵃ</td>
<td>109.4 (107.1–111.8)ᵃ</td>
<td>102.3 (100.0–104.7)ᵇ</td>
<td>108.4 (106.7–110.2)ᵃ</td>
</tr>
<tr>
<td>Ferritin, µg/L</td>
<td>n (499)</td>
<td>127</td>
<td>112</td>
<td>113</td>
</tr>
<tr>
<td>Means (95% CI)</td>
<td>40.3 (34.3–46.2)ᵃ</td>
<td>38.7 (32.4–45.0)ᵃ</td>
<td>43.2 (36.2–50.2)ᵃ</td>
<td>46.4 (41.2–51.5)ᵇ</td>
</tr>
<tr>
<td>TfR, mg/L</td>
<td>n (498)</td>
<td>127</td>
<td>112</td>
<td>113</td>
</tr>
<tr>
<td>Means (95% CI)</td>
<td>5.0 (4.5–5.4)ᵃ</td>
<td>5.0 (4.5–5.4)ᵃ</td>
<td>5.4 (4.9–6.0)ᵃ</td>
<td>5.5 (5.1–5.9)ᵃ</td>
</tr>
</tbody>
</table>

1 Seasons were defined as follows: winter (Dec/Jan/Feb), spring (Mar/Apr/May), summer (June/July/Aug) and fall (Sept/Oct/Nov).
2 Total sample size (in parentheses) varies from 563 due to missing values or insufficient plasma for analysis.
3 CI, confidence interval.
4 Values with different superscripts in a row differ significantly, $P < 0.05$ (ANOVA with Tukey’s studentized range test).
5 Vitamin B-6 as pyridoxal-5’-phosphate.

### Figure 2

Seasonal variations in the percentage of young Chinese women with abnormal concentrations of hemoglobin ($n = 557$), folic acid and vitamin B-6 ($n = 562$). Folate deficiency was defined as folic acid of <6.8 nmol/L and vitamin B-6 deficiency (as pyridoxal-5’-phosphate) of <30 nmol/L. For this figure, abnormal hemoglobin was defined as <100 g/L. Percentages vary significantly across seasons; $\chi^2 P = 0.001$ for folate and vitamin B-6 and $P = 0.01$ for hemoglobin. Sample sizes vary from 563 due to missing values.
cies were associated with megaloblastosis.

Without other hematologic measures, such as mean cell volume, we cannot determine whether severe B vitamin deficiency (60%) had a ferritin concentration of \( \text{mg/L} \), whereas severe folic acid deficiency (3%) of persons in Southern China (Xu et al. 1996), 75% of these had very mild anemia (Hb of 100–119 g/L), and 20% had Hb of <100 g/L. The high prevalence of mild anemia is consistent with data from the Chinese Institute of Nutrition and Food Hygiene (1985), which reported that 21–55% of “fertile women” were anemic. In a study of 447 nonpregnant female cotton mill workers in Beijing, Li et al. (1993) reported a mean Hb of 123 g/L, leading the authors to conclude that most of the anemia in their population was related to iron deficiency. In our study, the contribution of iron deficiency to anemia appears to be much smaller. We found that only 18% of all anemic women had ferritin <10 g/L, whereas 54% of our subjects with Hb of <100 g/L were deficient in at least one B vitamin. These findings suggest that in addition to iron deficiency, B vitamin deficiencies are contributing to the high prevalence of anemia in our population.

These anthropometric differences suggest that energy balance and perhaps overall nutritional status differed between the Anqing and Beijing textile workers, although without reliable dietary data for the two groups, it is impossible to conclude...
that such differences were necessarily related to nutrient intake. Nevertheless, it is clear from our data that women with low Hb concentrations were also more likely to have micronutrient deficiencies.

Poor micronutrient status among women of childbearing age jeopardizes their health and may influence their risk of achieving a normal pregnancy and delivering a healthy infant. Although we found a high prevalence of micronutrient deficiencies in Chinese textile workers of reproductive age, most of these deficiencies could be corrected easily and inexpensively through appropriate supplementation with B vitamins and iron. Family planning and antenatal care are available to these women, and the incorporation of nutritional counseling and therapy into these services could provide a convenient means of improving both maternal and infant health.

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