Association Between Serum Ferritin, Hemoglobin, Iron Intake, and Diabetes in Adults in Jiangsu, China

Zumin Shi, md, mphil[1,2]
Xiaoshu Hu, md[1]
Baojun Yuan, md[1]
Xiaoqun Pan, md[1]
Haakon E. Meyer, md, phd[2,3]
Gerd Holmboe-Ottesen, phd[2]

OBJECTIVE — To investigate the association between iron status, iron intake, and diabetes among Chinese adults.

RESEARCH DESIGN AND METHODS — This cross-sectional household survey was carried out in 2002 in Jiangsu Province, China. The sample contained 2,849 men and women aged ≥20 years with a response rate of 89.0%. Iron intake was assessed by food weighing plus consecutive individual 3-day food records. Fasting plasma glucose (FPG), serum ferritin, and hemoglobin were measured.

RESULTS — The prevalence of anemia was 18.3% in men and 31.5% in women. Mean hemoglobin and serum ferritin increased across groups with increasing FPG. The prevalence of anemia among women was 15.0% in individuals with FPG >7.0 mmol/l compared with 32.6% in individuals with FPG <5.6 mmol/l. There was a similar, however not significant, trend among men. In women, after adjusting for known risk factors, the odds ratio (OR) of diabetes was 2.15 (95% CI 1.03–4.51) for subjects in the upper quartile of hemoglobin compared with the rest, and the corresponding OR for the upper quartile of serum ferritin was 3.79 (1.72–8.36). Iron intake was positively associated with diabetes in women; fourth quartile intake of iron yielded an OR of 5.53 (1.47–20.44) compared with the first quartile in the multivariate analyses. In men, similar trends were suggested, although they were not statistically significant.

CONCLUSIONS — Iron status and iron intake was independently associated with risk of diabetes in Chinese women but not in men.

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There is an increasing concern about the relationship between iron status and type 2 diabetes (1–6). Excessive body iron is found to be associated with diabetes and the metabolic syndrome (7,8). One prospective cohort study in the U.S. showed that heme iron intake from red meat sources was positively associated with the risk of type 2 diabetes, whereas total iron intake and heme iron intake from non–red meat sources were not associated with the risk of type 2 diabetes (9). Anemia is a big health problem in many developing countries. The prevalence of anemia in China is high (15.2% on average) (10). Although there are different factors associated with low hemoglobin level, the most common cause of anemia in developing countries is iron deficiency (11). Interestingly, in a study from China, iron deficiency anemia was found to be independently associated with a reduced prevalence of gestational diabetes (12). One assumption was that this association could be an indicator of general nutritional deficiency.

The Chinese food pattern is unique in that it is characterized by a high intake of cereals and vegetables and a low intake of animal foods. This would imply that the intake of heme iron is low and the bioavailability of dietary iron is low. We therefore set out to examine the association between hemoglobin, serum ferritin level, iron intake, and diabetes in a cross-sectional study in the Jiangsu Province of China.

RESEARCH DESIGN AND METHODS

— In 2002, China launched a national nutrition and health study. The data presented in this article are based on subsamples from the Jiangsu Province in Eastern China. The rural sample was selected from six counties (Jiangyin, Taicang, Suning, Jurong, Sihong, and Haimen). From each of the six counties, three smaller towns were randomly selected. The urban sample was selected from the capital cities of the two prefectures, Nanjing and Xuzhou, and from each capital city, three streets were randomly selected. The six counties and the two prefectures represented a geographically and economically diverse population. In each town/street, two villages/neighborhoods were randomly selected, and 30 households were further selected randomly from each village/neighborhood. All the members in the households were invited to take part in the study. Written consent was obtained from all the participants. In the study presented here, we only analyzed data for adults aged ≥20 years.

Measurement and interview

Participants were interviewed in their homes by trained health workers using a precoded questionnaire.

Hemoglobin, serum ferritin, and fasting plasma glucose. All the participants were invited to take a fasting blood sample. The blood samples were analyzed for plasma glucose and hemoglobin in the local centers for disease control and prevention. hemoglobin was measured by the cyanmethemoglobin method (13). Serum ferritin was analyzed in a laboratory in the National Center for Disease Control and

From the [1]Jiangsu Provincial Center for Disease Control and Prevention, Nanjing, China; [2]General Practice and Community Medicine, University of Oslo, Oslo, Norway; and the [3]Norwegian Institute of Public Health, Oslo, Norway.
Address correspondence and reprint requests to Zumin Shi, Nutrition and Food Hygiene, Jiangsu Provincial Center for Disease Control and Prevention, 172 Jiangsu Rd., Nanjing 210009, P.R. China. E-mail: zumins@vip.sina.com.
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Abbreviations: FPG, fasting plasma glucose; HBsAg, hepatitis B surface antigen.
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Prevention in Beijing using a commercially available radioimmunoassay kit (Beijing North Institute of Biological Technology).

Anemia was defined as hemoglobin level <13 g/dl for men and <12 g/dl for women (11). Iron deficiency anemia was defined as the presence of both anemia and a serum ferritin level <15 μg/l. We defined diabetes as fasting plasma glucose (FPG) >7.0 mmol/l.

Dietary measurements. Dietary data were obtained by food weighing plus consecutive individual 3-day food records. Food consumption data were analyzed using the Chinese Food Composition Table (14).

Smoking and drinking. Smoking was assessed by asking the frequency of daily cigarette smoking. Drinking was assessed by asking the frequency and amount of alcohol/wine intake.

Height, weight, waist circumference, and blood pressure. At the study site, health workers measured height, weight, and blood pressure. Blood pressure was measured by mercury sphygmomanometer on the right upper arm of the subject, who was seated for 5 min before the measurement. Blood pressure was measured twice, and the mean of these two measurements was used in the analyses. Hypertension was defined as systolic blood pressure >140 mmHg and/or diastolic blood pressure >90 mmHg or use of antihypertensive drugs. Height was measured without shoes, and weight was measured with light clothing. BMI was calculated as weight in kilograms divided by the square of height in meters. Waist circumference was measured at midway between the inferior margin of the last rib and the iliac crest in a horizontal plane.

Family history of diabetes was defined as the presence of known family members with type 2 diabetes in any of three generations (siblings, parents, or grandparents).

Income level was assessed by the questions on family income and number of individuals in the household. It was constructed into three groups: low: <1,999 Yuan/person; medium: 2,000–4,999 Yuan/person; and high: >5,000 Yuan/person. Education was recoded into three categories based on six education categories in the questionnaire: low: illiteracy, primary school; medium: junior middle school; and high: high middle school or higher. Occupation was recoded into manual or nonmanual based on a question with 12 occupational categories.

Table 1—*Characteristic of the sample*

	Men	Women
n	1,308	1,541
Age (years)	47.2 ± 14.6	46.8 ± 14.4
Hemoglobin (g/dl)	14.3 ± 1.7	12.7 ± 1.5
Anemia (%)*	18.3	31.5
Serum ferritin (μg/l)	131.9 ± 90.1	71.1 ± 71.5
First quartile	42.2 ± 16.6 (3.7)	12.7 ± 5.8 (0.21)
Second quartile	89.1 ± 12.8 (66.7)	33.8 ± 7.2 (22.3)
Third quartile	140.3 ± 18.3 (111.1)	68.6 ± 13.8 (47.3)
Fourth quartile	257.4 ± 77.7 (175.6)	170.2 ± 74.8 (95.6)
Iron intake (mg/day)	28.2 ± 12.0	23.4 ± 9.5
BMI (kg/m^2)	23.4 ± 3.2	23.6 ± 3.7
Central obesity (%)†	19.5	38.2
High blood pressure (%)	30.5	24.5
Smoking		
Never (%)	42.9	97.3
1–19 cigarettes/day (%)	27.8	2.1
≥20 cigarettes/day (%)	29.3	0.5
Drinking		
0 times/week (%)	50.7	94.2
1–2 times/week (%)	14.3	2.3
3–4 times/week (%)	8.7	1.2
Daily (%)	26.3	2.2
FPG categories (mmol/l)		
<5.6 (%)	90.4	91.0
5.6–6.0 (%)	3.4	4.0
6.1–7.0 (%)	3.2	2.5
>7 (%)	3.0	2.6
Urban dwellers (%)	25.2	24.7
Manual jobs (%)	54.1	50.4
Education		
Low (%)	36.0	57.5
Medium (%)	43.5	30.1
High (%)	20.5	12.4

Data are means ± SD or means ± SD (minimum) unless otherwise indicated. *Hemoglobin level <13 g/dl for men and <12 g/dl for women. †Defined as waist circumference: men ≥90 cm, women ≥80 cm.

Statistical analyses

The subjects were classified according to sex-specific quartiles of hemoglobin, serum ferritin, and iron intake. The χ^2 test was used to compare differences between categorical variables, and ANOVA was used to compare differences between continuous variables. The association between hemoglobin, serum ferritin, iron intake, and the risk of type 2 diabetes was analyzed using logistic regression models. The analyses were adjusted first for age and then further for BMI, central obesity, family history of diabetes, high blood pressure, education, occupation, income, urban residence, smoking, drinking, and iron intake. In addition, energy, protein, and fat intake were adjusted for when estimating the association between iron intake and diabetes. Statistical significance was considered when *P* was <0.05. All statistical analyses were performed with SPSS for Windows 12.0 (SPSS, Chicago, IL).

RESULTS — In total, 1,417 households were included in the study. The final sample contained 1,308 men and 1,541 women. A total of 288 subjects were not present in the household during the period of the survey, giving a response rate of 89.0%. The prevalence of anemia was 18.3% in men and 31.5% in women (Table 1). Women had lower mean hemoglobin and serum ferritin than men. In total, 9.1% of the sample had serum ferritin <15 μg/l. The prevalence of iron deficiency anemia was 6.3% (n = 97) in women and 0.7% (n = 9) in men. The prevalence of high FPG (FPG >7.0 mmol/l) was 3.0% (n = 39) in men and 2.6% (n = 40) in women. In total, 19 men

Table 2—*Sample characteristic across FPG categories in Chinese adults* (n = *2,849*)

	FPG (mmol/l)				
	<5.6	5.6–6.0	6.1–7.0	>7.0	*P*
Food and nutrients intake (means ± SE)					
Energy (kcal)*	2,366 ± 13	2,193 ± 67	2,253 ± 76	2,160 ± 77	<0.001
Protein (g)*	72.3 ± 0.3	75.3 ± 1.5	74.9 ± 1.7	77.0 ± 1.7	0.005
Fat (g)*	80.2 ± 0.5	83.4 ± 2.6	86.8 ± 3.0	90.4 ± 3.0	<0.001
Carbohydrate (g)*	325 ± 1	319 ± 6	309 ± 7	301 ± 7	0.001
Iron (mg)†	25.5 ± 0.2	27.5 ± 0.8	26.1 ± 1.0	27.9 ± 1.0	0.009
Alcohol (g)†	1.9 ± 0.1	1.4 ± 0.5	1.7 ± 0.6	1.4 ± 0.6	0.679
Central obesity (%)‡	28.4	36.8	38.5	51.6	<0.001
Manual job (%)*	53.1	48.2	45.1	33.1	0.002
Hemoglobin (g/dl) (means ± SD)					
Men	14.3 ± 1.7	14.5 ± 1.8	14.5 ± 1.8	14.7 ± 1.9	0.372
Women	12.6 ± 1.5	12.7 ± 1.3	12.9 ± 1.8	13.4 ± 1.2	0.017
All	13.4 ± 1.8	13.5 ± 1.8	13.7 ± 2.0	14.1 ± 1.7	0.008
Anemia (%)					
Men	18.6	17.8	14.3	15.4	0.418
Women	32.6	23.0	21.1	15.0	0.002
All	26.2	20.8	17.5	15.2	0.003
Hemoglobin, fourth quartile (%)					
Men	24.1	27.3	34.1	38.5	0.013
Women	24.2	19.7	34.2	45.0	0.005
All	24.2	22.9	34.2	41.8	<0.001
Serum ferritin (μg/l) (means ± SD)§					
Men	130.7 ± 87.9	116.0 ± 79.3	160.6 ± 125.6	155.5 ± 113.1	0.144
Women	67.1 ± 67.7	91.9 ± 64.5	96.3 ± 80.0	158.0 ± 123.8	<0.001
All	96.2 ± 83.9	102.1 ± 71.8	129.7 ± 110.3	156.8 ± 117.8	<0.001
Serum ferritin, fourth quartile (%)					
Men	24.3	22.2	31.7	36.8	0.062
Women	22.6	44.3	36.8	64.1	<0.001
All	23.4	34.9	34.2	50.6	<0.001

*ANCOVA, age-adjusted. †ANCOVA, energy- and age-adjusted. ‡ANCOVA, age-adjusted. Central obesity defined as waist circumference: men ≥90 cm, women ≥80 cm. §Not homogeneity; Welch adjustment was used.

and 32 women were known to have diabetes. Of these, 8 men and 15 women had FPG <7.0 mmol/l and were excluded from further analyses. About 4% of the total sample reported having a family history of diabetes.

The mean daily intake of iron was 40.2 mg in the highest quartile compared with 15.4 mg in the lowest quartile of intake. Iron intake was negatively associated with anemia, illustrated by the fact that the prevalence of anemia decreased from 34.5% in the lowest quartile to 17.0% in the highest quartile of iron intake.

Iron intake was significantly associated with hemoglobin level (Spearman $r = 0.259$, $P < 0.001$). There was a weak association between iron intake and serum ferritin (Spearman $r = 0.045$, $P = 0.017$). The mean ± SD daily intake of red meat was 0, 33.4 ± 12.1, 75.4 ± 14.7, and 158.0 ± 52.1 g across quartiles of red meat intake. Alcohol intake was positively associated with serum ferritin (Spearman $r = 0.17$, $P < 0.001$).

Significant differences in intake of energy, protein, fat, and iron were observed between FPG groups (Table 2).

Mean hemoglobin increased, and the prevalence of anemia decreased across FPG groups from low to high in women, whereas in men, these trends were not significant (Table 2). There was a clear increasing trend in the proportion of the sample belonging to the highest hemoglobin quartile across the FPG categories from low to high both in men and women, and this prevalence was twice as high in women with FPG >7 mmol/l compared with women with FPG <5.6 mmol/l.

In women, mean serum ferritin was much higher in individuals with FPG >7 mmol/l compared with individuals with FPG <5.6 mmol/l (158.0 vs. 67.1 g/l), and 64.1% of the women with FPG >7 mmol/l had serum ferritin in the highest quartile compared with 22.6% in individuals with FPG <5.6 mmol/l. Similar but weaker and nonsignificant trends were found in men.

In multivariate analysis, higher hemoglobin was positively associated with diabetes in women (Table 3). After adjusting for age, BMI, central obesity, smoking, drinking, family history of diabetes, high blood pressure, urban residence, income, occupation, high serum ferritin, intake of iron, energy, protein, and fat, the highest hemoglobin quartile had an odds ratio (OR) of 2.15 (95% CI 1.03–4.51) for diabetes in women compared with the lowest quartile. The same association was also found between higher serum ferritin and diabetes with an OR of 3.79 (1.72–8.36) after adjustment for the above factors. This association was still significant when further adjusted for iron intake. In men, higher hemoglobin was positively, but not significantly, associated with diabetes. Anemic participants were found to have lower risk of diabetes. In multivariate analyses, the OR of diabetes was 0.43 (0.23–0.81) for the anemic participants

Table 3—*ORs for type 2 diabetes associated with hemoglobin and serum ferritin in a sample of Chinese adults* (n = 2,849)

	Quartile 4 vs. 1–3 of hemoglobin	Quartile 4 vs. 1–3 of serum ferritin
Men		
Model 1*	2.23 (1.14–5.35)	1.80 (0.92–3.53)
Model 2†	1.86 (0.94–3.67)	1.40 (0.70–2.80)
Model 3‡	1.66 (0.82–3.35)	1.26 (0.61–2.60)
Model 4§	1.65 (0.80–3.94)	1.06 (0.50–2.23)
Model 5‖	1.74 (0.83–3.63)	1.08 (0.50–2.33)
Model 6¶	1.86 (0.88–3.92)	1.09 (0.51–2.35)
Model 7#	1.75 (0.71–4.27)	1.09 (0.51–2.35)
Women		
Model 1*	2.75 (1.45–5.23)	4.16 (2.04–8.45)
Model 2†	2.45 (1.27–4.70)	3.93 (1.92–8.05)
Model 3‡	2.32 (1.18–4.55)	3.92 (1.89–8.13)
Model 4§	2.07 (1.03–4.15)	3.94 (1.83–8.49)
Model 5‖	2.12 (1.04–4.33)	4.07 (1.86–8.90)
Model 6¶	2.15 (1.03–4.51)	3.79 (1.72–8.36)
Model 7#	2.69 (0.98–7.39)	4.59 (1.49–14.13)
Both sexes		
Model 8**	1.97 (1.18–3.28)	1.98 (1.19–3.29)

Data are OR (95% CI). *Adjusted for age. †Adjusted for age, BMI (continuous), central obesity (waist circumference: men ≥90 cm, women ≥80 cm). ‡Adjusted for age, BMI (continuous), central obesity, smoking (never, past, and current smoking of 1–19 or ≥20 cigarettes/day), drinking (0 times/week, 1–2 times/week, 3–4 times/week, or daily), family history of diabetes in any of three generations (siblings, parents, or grandparents), high blood pressure (diastolic blood pressure ≥90 mmHg and/or systolic blood pressure ≥140 mmHg or using antihypertensive drugs). §Adjusted for variables in model 3 and urban, income (low, medium, high), job (manual, non-manual), and education. ‖Adjusted for variables in model 4 and intake of iron (quartiles), energy, protein, and fat. ¶Adjusted for variables in model 5 and high hemoglobin (fourth quartile) and high serum ferritin (fourth quartile). #Adjusted for variables in model 6 and after excluding 51 participants with known diabetes. **Adjusted for variables in model 6 and sex. In this model, sex was not significant, but family history of diabetes yields an OR of 3.86 (95% CI 1.82–8.16).

compared with the nonanemic after adjusting for age and sex, and the corresponding OR in the full model (confer model 5, Table 3) was 0.49 (0.25–0.99). Further sex-specific analyses showed a significant inverse association between anemia and diabetes in women but not in men.

Iron intake was positively associated with diabetes in multivariate logistic regression in women (Table 4). There was a linear trend of risk across quartiles of iron intake. After adjusting for energy and fat intake and other sociodemographic and lifestyle factors, the OR of diabetes was about six times higher in the fourth compared with the first quartile of iron intake (model 5). Further adjustment for high hemoglobin and serum ferritin did not change the associations (model 6 and 7). The association between iron intake and diabetes was not significant in men. Alcohol intake was not associated with diabetes (data not shown).

In another analysis, excluding 43 individuals who reported to have taken medication to control diabetes, the association between hemoglobin, serum ferritin, iron intake, and diabetes were similar but with wider CIs due to a reduced number of end points (data not shown). In the multivariate analysis with combined sexes, the OR of diabetes was ~2 for both high hemoglobin and high serum ferritin (model 8). The OR of diabetes for the fourth quartile intake of iron was ~4 compared with the first quartile.

CONCLUSIONS — In this cross-sectional study, we found an inverse association between anemia and diabetes. Higher hemoglobin and serum ferritin were both associated with high risk of diabetes, predominantly in women. Iron intake was also positively associated with diabetes. These associations were still present after adjusting for known risk factors, including sociodemographic characteristics, BMI, central obesity, hypertension, family history of diabetes, and lifestyle factors.

Limitation of the study

The power to study diabetes in men was low. This could be one of the reasons why the association between iron status and diabetes was only significant in women. Serum ferritin is the most commonly used marker of stored body iron (15). However, serum ferritin is positively and hemoglobin is negatively associated by inflammation and infection (16). We do not have information on C-reactive protein, which is often used as an indicator of inflammation or infection. The association between hemoglobin and serum ferritin may thus be confounded by these conditions. In our results, we found a high prevalence of anemia (18.3 and 31.5%, for men and women, respectively), but the percentage having serum ferritin <15 μg/l was only ~9%. The prevalence of iron deficiency anemia was thus low: 6.3% among women and 0.7% among men. Thalassemia is not a problem in this area, with a prevalence of 0.09% (17).

It is reported that the prevalence of the hepatitis B virus marker is 42.6% and hepatitis B surface antigen (HBsAg) carriage is 10.2% in various parts of China (18). A study on Chinese pregnant women found that HBsAg carriage was a risk factor for gestational diabetes (19). Mean serum ferritin concentration has also been found to be higher among ethnic Chinese than other ethnic groups in Singapore (20). The mean serum ferritin in our sample was comparable to the finding in Singapore. Although our results could be confounded by the high prevalence of HBsAg carriage and other types of inflammation or infection, the negative association between low hemoglobin and diabetes in our sample is not likely to be confounded by these factors, nor the association between iron intake and diabetes.

Smoking and alcohol drinking has been shown to be associated with an increased level of serum ferritin (21,22). In our sample, about half of the men were smokers and drinkers. In our data, we observe a correlation between alcohol drinking and serum ferritin. But whether we adjusted for drinkers/nondrinkers or nondrinkers/light drinkers/heavy drinkers, the association between serum ferritin and diabetes did not change. Furthermore, few women in our sample were smokers and drinkers, and the association between serum ferritin and diabetes was even stronger among women.

Hemoglobin concentration may be

Table 4—*OR (95% CI) for type 2 diabetes according to quartiles of iron daily intake in Chinese adults* (n = 2,849)

	Iron intake quartiles				
	Quartile 1 (low)	Quartile 2	Quartile 3	Quartile 4 (high)	*P* for trend
Men					
Model 1*	1	0.74 (0.27–2.00)	0.85 (0.30–2.41)	1.76 (0.57–5.37)	0.329
Model 2†	1	0.80 (0.24–2.16)	0.95 (0.34–2.71)	1.85 (0.60–5.74)	0.284
Model 3‡	1	0.67 (0.24–1.87)	0.92 (0.32–2.67)	1.82 (0.57–5.82)	0.310
Model 4§	1	0.61 (0.22–1.74)	0.84 (0.28–2.49)	1.48 (0.44–5.00)	0.530
Model 5‖	1	0.58 (0.20–1.69)	0.88 (0.29–2.65)	1.54 (0.44–5.37)	0.494
Model 6¶	1	0.55 (0.19–1.63)	0.88 (0.29–2.66)	1.50 (0.43–5.21)	0.524
Model 7#	1	0.61 (0.21–1.76)	0.82 (0.26–2.55)	1.73 (0.50–6.01)	0.392
Women					
Model 1*	1	2.29 (0.93–5.68)	2.91 (1.02–8.27)	4.75 (1.47–15.40)	0.009
Model 2†	1	2.86 (1.13–7.22)	3.69 (1.26–10.82)	5.33 (1.62–17.56)	0.006
Model 3‡	1	2.72 (1.07–6.92)	4.09 (1.37–12.24)	5.67 (1.67–19.18)	0.005
Model 4§	1	2.70 (1.01–7.19)	3.84 (1.22–12.02)	5.31 (1.47–19.26)	0.011
Model 5‖	1	2.66 (0.99–7.12)	3.41 (1.07–10.91)	5.53 (1.47–20.44)	0.012
Model 6¶	1	2.65 (0.98–7.13)	3.65 (1.13–11.79)	5.40 (1.43–20.44)	0.013
Model 7#	1	2.59 (0.93–7.23)	3.59 (1.08–11.96)	5.91 (1.49–23.41)	0.012
Both sexes					
Model 8**	1	1.42 (0.69–2.93)	2.17 (0.96–4.91)	3.73 (1.50–9.26)	0.004

*Adjusted for energy, protein, and fat intake. †Adjusted for energy, protein, fat intake, and age. ‡Adjusted for energy, fat intake, protein, age, BMI (continuous), and central obesity (waist circumference: men ≥90 cm, women ≥80 cm). §Adjusted for variables in model 3 and smoking (never, past, and current smoking of 1–19 or ≥20 cigarettes/day), drinking (0 times/week, 1–2 times/week, 3–4 times/week, or daily), family history of diabetes in any of three generations (siblings, parents, or grandparents), and high blood pressure (diastolic blood pressure ≥90 mmHg and/or systolic blood pressure ≥140 mmHg or using antihypertensive drugs). ‖Adjusted for variables in model 4 and residence (urban/rural), income (low/medium/high), job (manual/not manual), and education (primary, junior middle school, high middle school/university). ¶Adjusted for variables in model 5 and high hemoglobin (fourth quartile). #Adjusted for variables in model 5 and high serum ferritin (fourth quartile). **Adjusted for variables in model 5 and high hemoglobin (fourth quartile) and serum ferritin (fourth quartile) and sex. In this model, sex was not associated with diabetes.

positively influenced by factors such as living at a high altitude, cigarette smoking, and hypertension (23,24). In the sample, 30.5% of men and 24.5% of women had high blood pressure. Thus, the high hemoglobin may partly be linked to high blood pressure. But this influence must be small, since adjusting for high blood pressure still left the association between high hemoglobin and diabetes significant.

Present studies on the relationship between iron stores and diabetes are mainly done in Western countries. Few studies have been done in Asian populations (12,19). Possible mechanisms by which body iron stores increase diabetes risk might be by promoting both insulin resistance and increased oxidative stress (5,25). There is also a suggestion that free iron is more important in the association between iron and diabetes (22). In our study, we found a graded association between hemoglobin, serum ferritin, and FPG. Higher hemoglobin and serum ferritin were associated with diabetes after adjusting for the known risk factors of diabetes. The ORs were found to be ~2. Cutoffs of serum ferritin >300 μg/l for men and serum ferritin >200 μg/l for women have been suggested as criteria for iron overload. In our sample, the mean serum ferritin in the fourth quartile was 257.4 μg/l for men and 170.2 μg/l for women. This result may suggest a status of iron overload among some in this group. However, the minimum of serum ferritin in this group was low: 175.6 and 95.6 μg/l among men and women, respectively. Our results support the suggestion that a better definition of excessive iron stores in healthy people is needed (26).

In the study by Jiang et al. (9), among U.S. men, only heme iron was found to be related to diabetes. In the Chinese population, the average intake of animal foods is low. The main source of iron is from plant foods, which contain mainly non-heme iron, and daily red meat intake was <70 g. We found a linear trend of risk of diabetes across quartiles of iron intake. This trend remained stable in multivariate models adjusted for different variables. It may suggest that non-heme iron may also play a role in the association between iron status and diabetes in the Chinese context. Because this study is a cross-sectional study, we cannot establish the causal relationship. It also could be that high iron intake is a marker of other unknown factors correlated to food intake, e.g., pesticide residue, which is found to be a risk factor of diabetes (27), or nutrient composition. In our sample, subjects with the highest FPG had the lowest caloric intake. However, they were also more obese, suggesting a more positive energy balance compared with individuals with lower FBG due to a more sedentary lifestyle.

In spite of the limitation of the study, the results were consistent with some previously reported results of the association between iron stores and diabetes in an area with high prevalence of anemia in China.

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