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Association Between Chilli Food Habits with Iron Status and Insulin Resistance in a Chinese Population

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ABSTRACT Some studies have indicated that the consumption of chilli-containing foods can influence iron absorption and affect serum insulin and glucose concentrations, which may help to alleviate diabetes or prediabetes. The objective of this study was to explore the relationship between chilli food habits with iron status and insulin resistance in the Chinese population. Fasting blood samples, anthropometric data, and chilli food habit data collected from 8433 adults (aged 18 to 99), in 2009, as part of the China Health and Nutrition Survey, a large-scale longitudinal, household-based survey in China. Chilli food habits were assessed using chilli food eating frequencies (no eating, sometimes eating, often eating, and usually eating) and chilli food types (a little bit hot, moderately hot, and very hot). Fasting serum ferritin, insulin, and fasting plasma glucose were also measured. The homeostasis model assessment of insulin resistance (HOMA-IR) was used to estimate insulin resistance. Compared with the chilli-eating group, the no eating group had higher HOMA-IR levels for both men and women ($P < .05$). There were significant differences in HOMA-IR ($P < .05$) for both men and women and in ferritin ($P < .001$) for women according to different chilli food types. However, there was no significant difference in the ferritin level and HOMA-IR components for different chilli food eating frequencies in both sex groups. Chilli food habits, especially the different hotness levels of chilli food, were associated with iron status and insulin resistance in the Chinese population. Additional studies are needed to elucidate mechanisms of action and to establish causal inference.

KEY WORDS: • ***diabetes*** • ***health functional food*** • ***iron*** • ***nutrition***

INTRODUCTION

In the Chinese food culture, chillies are common and important spices, which contribute significantly to the taste and flavor of Chinese food. Research over the past three decades has indicated several potential beneficial health effects of spices (e.g., turmeric, cinnamon, garlic, and chilli), especially concerning lipid metabolism, diabetic control, digestive function, and antioxidative potential.[1]

Chillies, especially red chillies, contain large amounts of vitamin C and small amounts of carotene (provitamin A). They are also a good source of most B vitamins. In addition, they are very high in potassium, magnesium, and iron. Their very high vitamin C content can substantially increase the uptake of nonheme iron from other ingredients in food, such as beans and grains. However, vegetables and fruits, including chillies, also contain high amounts of polyphenols and phytate, which are the main inhibitors of iron absorption.[2] Tuntipopipat *et al.*[3] reported that chillies can inhibit iron absorption in young Thai women.

Iron is a transition metal that can convert poorly reactive free radicals into highly reactive moieties, which can cause oxidative damage to cells and tissues. Increased accumulation of iron in patients with hemochromatosis or hematological diseases affects the synthesis and secretion of insulin by the pancreas and compromises insulin action in target tissues.[4] A recent study by Kim *et al.*[5] reported that serum ferritin concentrations may be associated with insulin resistance and impaired glucose metabolism in the Korean population. Another study concluded that chilli consumption may attenuate postprandial hyperinsulinemia.[1]

Do chilli food habits affect iron status and insulin resistance in humans? We hope to explore the association between chilli food habits with iron status and insulin resistance among a free-living Chinese population by using a representative, randomly selected sample from nine provinces across China.

MATERIALS AND METHODS

Study population

The data were extracted from the China Health and Nutrition Survey (CHNS), a large-scale longitudinal, household-based

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survey in China.[6] The CHNS has followed individuals randomly selected from 228 communities since 1989, and was designed to represent a set of large provinces, with a range of economic and demographic variations, covering approximately 56% of China's population, including Heilongjiang, Liaoning, Shandong, Henan, Hubei, Hunan, Jiangsu, Guangxi, and Guizhou (from north to south).[7–9] A multistage, random cluster process was used to draw the surveyed sample. Counties in the nine provinces were initially stratified by income (low, middle, and high) and a weighted sampling scheme was used to randomly select four counties in each province. A higher income city and a lower income city within each province were selected. In addition, the township capital and three villages within the counties were randomly selected. Finally, within each city, urban and suburban neighborhoods were randomly selected. In each community, 20 households were interviewed. The 2009 CHNS sample consists of 216 communities from 9 provinces, comprising 36 urban neighborhoods, 36 suburban neighborhoods, 36 towns, and 108 villages. Details about the study design and sampling strategies are reported elsewhere.[6,10,11]

In total, 8641 fasting blood samples were drawn from adult participants (aged 18–99 years). Two hundred eight participants who did not have serum ferritin due to a serious hemolytic state or did not have chilli food habit information were excluded in the analysis. Therefore, we analyzed the association between chilli food habits and iron status and insulin resistance among 8433 participants (aged 18–99 years).

Data collection methods

Trained interviewers (physicians and nutritionists) collected questionnaire-based demographic, anthropometric, and lifestyle data from each participant, including date of birth, sex, ethnicity, occupation, education level, health status, health behavior (smoking habit, alcohol use, and physical activity), food and beverage intake, tea intake, diseases under current or previous treatment, use of drugs and supplements, parental history of selected diseases, and blood collection control information (collection time, treatment time, transfer time, and storage time). Smoking status was grouped as nonsmokers, past smokers, and current smokers. Alcohol drinking was classified based on reported consumption frequencies (three or more times/week, one to two times/week, one to two times/month, less than one time/month, and nondrinker). The education level was categorized into three groups (primary school or below, middle and high school, and above high school).

Chilli food habits were classified based on chilli food eating frequencies (no eating, sometimes eating, often eating, and usually eating) and chilli food types (a little hot, moderately hot, and very hot).

Participants who signed the blood consent form in the study were required to fast overnight (at least 8 h) before the blood collection by trained phlebotomists under standard protocol.[6] Blood was drawn from an antecubital vein in the morning and was transferred to the local hospital for further treatment within 2 h of blood collection. Blood specimens were collected in a 4-mL EDTA vacuum tube for routine examination and two 4-mL separation gel vacuum tubes for biochemical analysis, and were stored in an icebox in the field. When specimens were transferred to the local hospital, they were centrifuged at 3000 *g* for 10 min at room temperature as soon as possible and separated into nine aliquots. Aside from the samples for field tests, other samples were stored in −80°C freezers.

The fasting serum glucose (enzymatic method) was measured at local hospitals. The calibrator and control serums were provided by the Central Laboratory of the Clinical Laboratory Department of China-Japan Friendship Hospital (CJFH) using the same lot number. Other biochemical markers were analyzed at the Central Laboratory of CJFH. The concentration of fasting serum insulin and ferritin was determined by a commercial radioimmunoassay kit (Beijing North Institute of Biological Technology, Beijing, China). The interassay coefficient of variation (CV) was less than 15% and the intra-assay CV was less than 10%. The sensitivity was 2 μIU/mL. Insulin resistance was estimated using a homeostasis model assessment (HOMA-IR) equation: HOMA-IR = fasting serum insulin (μIU/mL) × fasting serum glucose (mM)/22.5.

Statistical analysis

The current analysis was restricted to 8433 participants who had completed fasting blood sampling and chilli food data collection. For baseline characteristics of participants, medians (interquartile range) were used for continuous variables, and counts and percentages for categorical variables. Unpaired *t*-tests were used to compare continuous variables, and chi-square tests to compare categorical variables between sex groups.

To examine whether the effects of chilli food eating habit differences on ferritin concentrations and HOMA-IR were independent of age, smoking use, alcohol consumption, nationality, and carbohydrate consumption, we performed linear regression analyses with ferritin levels and HOMA-IR as the dependent variables.

To examine whether differences of iron status and insulin resistance according to different chilli food habit populations were independent of age, smoking, alcohol consumption, nationality, and carbohydrate consumption, we used multivariable logistic regression analyses to examine the association between ferritin levels, HOMA-IR, and chilli food habits. The odds ratios (ORs) and 95% confidence intervals for the ferritin level and HOMA-IR were calculated for different chilli food habits, with the lowest chilli food type and chilli food frequency as the reference. Tests for trends across quartiles were computed by including a variable with the median value for each quartile as a continuous variable in the logistic regression models. All of the reported P values were two tailed, and those <0.05 were considered to be statistically significant. The ORs of all components were adjusted for age, nationality, smoking use, alcohol consumption, and carbohydrate consumption in different regression models. Statistical analyses were performed with SAS 9.2 (SAS Institute, Cary, NC, USA).

RESULTS

In this survey, 8433 participants (3935 men and 4498 women) completed fasting blood samples and chilli food habit data collection. The baseline characteristics and the descriptive statistics of the study population are summarized in Table 1. The median age was 51.11 years (range, 18–99 years). Compared with women, men had higher body mass indices and systolic blood pressures. Men had a significantly higher rate of current smoking (54.89% versus 3.62%) and alcohol consumption (59.80% vs. 8.76%) than women.

Based on the chilli food habit data, the study population can first be separated into two groups: the chilli food eating group (5881 participants) and the no chilli food eating group (2551 participants). There were significant differences in HOMA-IR for both groups in both men and women ($P < .05$; Fig. 1A). The differences remained significant after further adjustment for age, nationality, smoking use, alcohol consumption, and carbohydrate consumption. Compared with the eating group, the no eating group had lower ferritin levels in men and higher ferritin levels in women ($P < .05$) (Fig. 1B). However, the difference became nonsignificant after adjusting for age in women ($P = .35$).

For the chilli food eating group, there was a significant difference in HOMA-IR ($P < .05$) for both men and women and in fasting serum Ferritin concentrations ($P < .001$) for women according to different chilli food types (Table 2).

The ORs for HOMA-IR decreased progressively across the chilli food levels ($P < .05$ for trend) in women and in men. After adjusting for age and nationality, the trend of the ORs of the men group remained significant. After adding smoking status, alcohol consumption, and carbohydrate consumption into the adjusted model, the trend significance disappeared (Table 3).

For chilli food eating frequencies, there was no significant difference in the fasting serum ferritin concentration and HOMA-IR for both sex groups (Tables 4 and 5).

DISCUSSION

As common spices, chillies are a good source of vitamin C, carotene, and most B vitamins. They are also very high in potassium, magnesium, and iron. Their very high vitamin C content can substantially increase the uptake of nonheme iron from food such as beans and grains. However, as vegetables and fruits, they also contain significant amounts of polyphenols and phytates, which are dietary factors that can impair iron absorption. These factors have been shown repeatedly to influence iron absorption in single-food isotope studies, whereas in multifood studies with varied diet and multiple inhibitors and enhancers, the effect of single components has been, as expected, more modest. The influence of vitamin A, carotenoids, and nondigestible carbohydrates on iron absorption and the nature of the meat factor remain unresolved.[2] Some

Table 1. Baseline Characteristics of Participants

	Total (n = *8433*)	*Men* (n = *3935*)	*Women* (n = *4498*)	Z *for sex comparison*
Age, years	51.11 (24.53–75.93)	51.22 (24.23–75.95)	50.99 (24.78–75.88)	0.81
BMI[a], kg/m^2	23.05 (18.23–29.62)	23.09 (18.29–29.38)	23.03 (18.20–29.74)	< 0.05
Waist circumference[b], cm	82.00 (66.50–100.10)	84.00 (68.00–102.00)	80.30 (65.20–99.10)	0.80
SBP[c], mm Hg	120.67 (100.00–160.00)	122.00 (100.67–160.00)	120.00 (97.67–161.33)	< 0.001
DBP[c], mm Hg	80.00 (62.00–100.00)	80.67 (66.00–100.67)	80.00 (60.67–100.00)	0.08
Smokers, *n* (%)				< 0.001
Never	5836 (69.20)	1516 (38.53)	4320 (96.04)	
Former	274 (3.25)	259 (6.58)	15 (0.33)	
Current	2323 (27.55)	2160 (54.89)	163 (3.62)	
Alcohol use/last year, *n* (%)				< 0.001
No	5686 (67.43)	1582 (40.20)	4104 (91.24)	
Yes	2747 (32.57)	2353 (59.80)	394 (8.76)	
Education, *n* (%)				< 0.001
Low	3656 (43.35)	1336 (33.95)	2320 (51.58)	
Medium	2782 (32.99)	1493 (37.94)	1298 (28.66)	
High	1995 (23.66)	1106 (28.11)	889 (19.76)	
History of diabetes	890 (10.55)	447 (11.36)	443 (9.85)	< 0.05
History of cardiovascular disease	82 (0.97)	39 (0.99)	43 (0.96)	0.87
History of stroke	117 (1.39)	79 (2.01)	38 (0.84)	< 0.001
History of hypertension	1114 (13.21)	500 (12.71)	614 (13.65)	0.20

Data are presented as median (5th percentile–95th percentile) or as number (percent). Chi-square test for categorical variables, the unpaired *t* test or Mann–Whitney *U* test for continuous variables.

[a]Information on BMI was available for 3904 men and 4478 women.

[b]Information on waist circumference was available for 3894 men and 4457 women.

[c]Information on SBP and DBP was available for 3933 men and 4495 women.

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

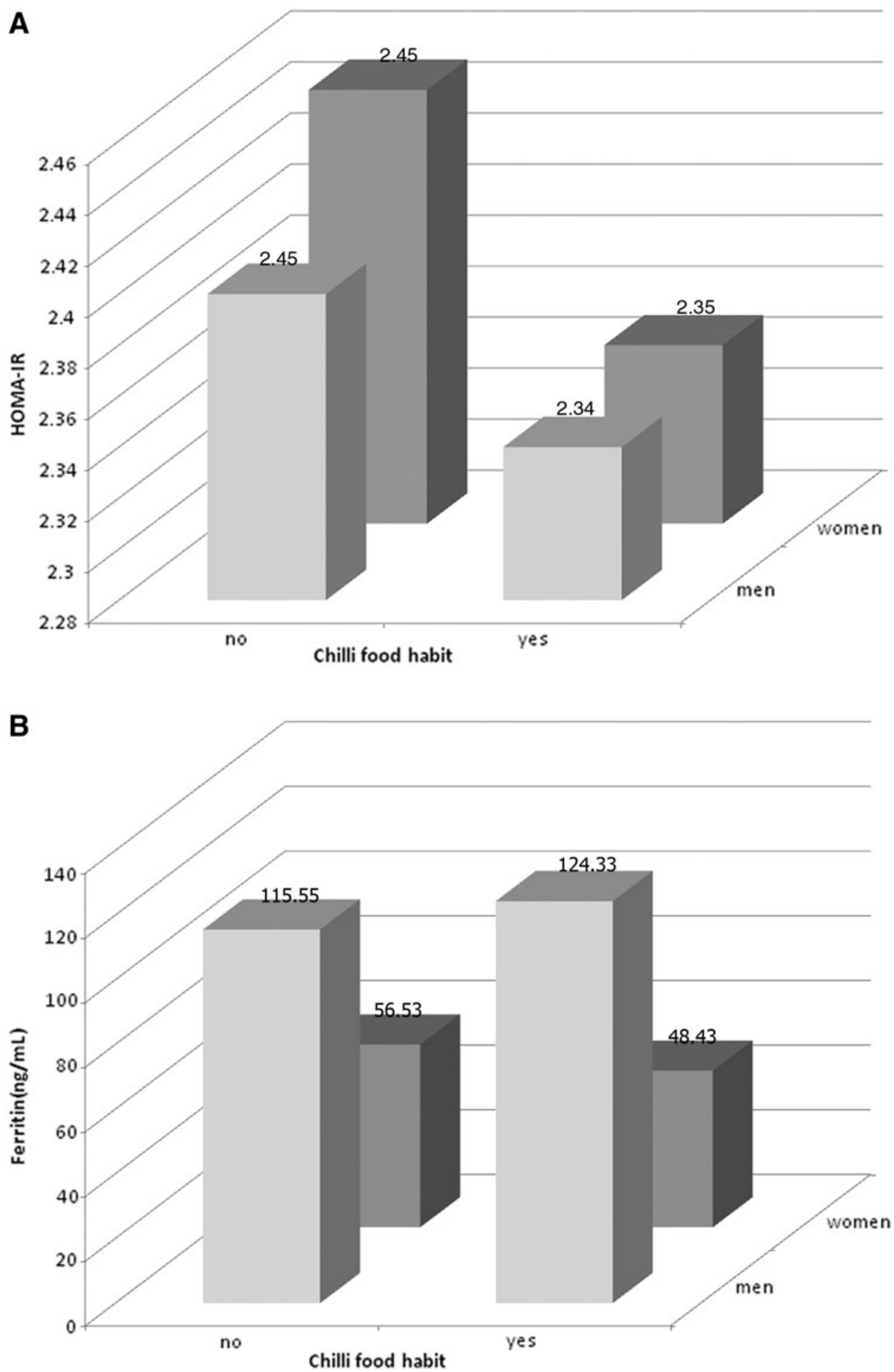

FIG. 1. The HOMA-IR **(A)** and concentrations of ferritin **(B)** in different sex groups according to chilli food habits. HOMA-IR, homeostasis model assessment of insulin resistance.

researchers think that chillies' very high vitamin C content can substantially increase the uptake of nonheme iron from other ingredients in food, such as beans and grains. However, Tuntipopipat *et al.*[3] indicated that being rich in phenolic compounds, chillies could be expected to bind iron $(Fe)^{3+}$ in the intestine and inhibit iron absorption in humans. They concluded that both phenol quality and quantity determine the inhibitory effect of phenolic compounds on iron absorption.

On the other hand, some studies indicated that chilli consumption may attenuate postprandial hyperinsulinemia.[1] Regular consumption of chilli may improve postprandial

Table 2. Comparison of Ferritin Concentrations and Insulin Resistance in Different Chilli Food Types

	A little bit hot	*Moderately hot*	*Very hot*	P *(trend)*
Men (*n*)[a]	1330	1261	266	
Ferritin (ng/mL)	126.68	130.50	122.80	0.485
HOMA-IR	2.48	2.40	2.19	<0.05
Women (*n*)[a]	1641	1190	194	
Ferritin (ng/mL)	60.52	58.75	46.46	<0.001
HOMA-IR	2.40	2.47	2.12	<0.05

[a]One man and two women reported that information on chilli food types is unknown.

HOMA-IR, homeostasis model assessment of insulin resistance.

glucose, insulin, and energy metabolism, and attenuate postprandial hyperinsulinemia.[12]

Iron, a necessary trace element that participates in many biological oxidations and accumulates in tissue, can lead to pathological changes in the liver, heart, endocrine organs, and musculoskeletal system.[13,14] Some studies in patients with hemochromatosis or hematologic diseases indicated that increased accumulation of iron affects the synthesis and secretion of insulin by the pancreas[15,16] and compromises insulin action in target tissues.[17–19] Therefore, it might contribute to the development of insulin resistance. Ferritin is a ubiquitous intracellular protein that can store and release iron and act as a buffer against iron deficiency and iron overload. Ferritin is widely used as a clinical biomarker to evaluate iron status. Increased serum ferritin concentrations in nonpathologic conditions, reflecting subclinical iron overload, have been reported to be associated with insulin resistance and an increased risk of type 2 diabetes mellitus.[5,20,21]

Therefore, the influence of chilli food habits on iron status and insulin resistance needs more clarification and additional studies. In this analysis, we confirmed that the no chilli eating group had higher HOMA-IR levels than the chilli eating group among men and women ($P<.05$). The difference remained significant after further adjusting for age, nationality, smoking use, alcohol consumption, and carbohydrate consumption. Even after adjusting by different regression models, the trend of ORs for HOMA-IR decreased progressively across the chilli food levels ($P<.05$ for trend) in men and remained significant. However, there was no significant difference in fasting serum ferritin concentrations and HOMA-IR among different chilli food eating frequencies in both sex groups. These results indicated that chilli food habits in the Chinese diet may affect insulin resistance. Eating chilli food can decrease insulin resistance.

Table 3. Comparison of Ferritin Concentrations and Insulin Resistance in Different Chilli Food Types

	A little bit hot	*Moderately hot*	*Very hot*	P *(trend)*
Men				
Ferritin	1	1.09 (0.95–1.25)	1.00 (0.79–1.27)	0.48
Model 1[a]	1	1.06 (0.92–1.21)	0.98 (0.77–1.24)	0.69
Model 2[b]	1	1.03 (0.90–1.19)	0.94 (0.74–1.19)	0.72
HOMA-IR	1	0.90 (0.78–1.03)	0.76 (0.60–0.97)	<0.05
Model 1	1	0.87 (0.76–1.00)	0.74 (0.59–0.94)	<0.05
Model 2	1	0.88 (0.76–1.01)	0.80 (0.63–1.01)	0.08
Women				
Ferritin	1	0.87 (0.76–1.00)	0.64 (0.49–0.83)	<0.05
Model 1	1	1.06 (0.93–1.22)	0.84 (0.64–1.11)	0.23
Model 2	1	1.06 (0.92–1.21)	0.83 (0.63–1.10)	0.25
HOMA-IR	1	0.91 (0.80–1.04)	0.73 (0.56–0.95)	<0.05
Model 1	1	0.95 (0.83–1.08)	0.77 (0.59–1.00)	0.14
Model 2	1	0.95 (0.83–1.08)	0.75 (0.57–0.98)	0.10

[a]Model 1, odds ratio adjusted for age.

[b]Model 2, odds ratio adjusted for model 1 plus nationality, smoking use, alcohol consumption, and carbohydrate consumption.

Table 4. Comparison of Ferritin Concentrations and Insulin Resistance in Different Chilli Food Eating Frequencies

	Sometimes	*Often*	*Usually*	P *(trend)*
Men (*n*)	1565	817	476	
Ferritin (ng/mL)	125.06	129.92	134.80	0.167
HOMA-IR	2.43	2.41	2.38	0.620
Women (*n*)	1715	812	500	
Ferritin (ng/mL)	58.70	55.30	61.75	0.167
HOMA-IR	2.39	2.38	2.48	0.467

There was no significant difference in iron absorption and insulin resistance components according to different chilli food eating frequencies in both sex groups. This indicates that the type of chillies may influence insulin resistance more than the quantity of chillies, which is consistent with the results of the study by Tuntipopipat *et al.*[3]

All the results indicated no significant differences in fasting serum ferritin concentrations on chilli food eating, chilli food types, and chilli food frequencies. The relationship between chilli and iron absorption needs further investigation.

To our knowledge, this is the largest population-based study to describe the association between chilli food habits with iron status and insulin resistance in the Chinese population. One of the advantages of our study is that the data came from a large-scale longitudinal, household-based survey. Having a much larger sample size can provide a more representative sample of the Chinese population. The participants in this study were recruited from nine provinces, including urban, suburban, town, and village population, representing a wide variety of Chinese and their food cultures.

We have a few limitations as well. This cross-sectional analysis does not examine temporal changes in iron status and insulin resistance owing to the fact that biomarker data were only collected in the 2009 round of the CHNS. Also, due to the limitations of the survey design, some key variables are not available in this study.

Chilli food habits, including chilli food eating and chilli food type, were associated with insulin resistance in the Chinese population. Additional studies are needed to elucidate mechanisms of action and to establish causal inference. This may help to reduce diabetes or prediabetes.

TABLE 5. ODDS RATIOS AND ADJUSTED ODDS RATIOS OF FERRITIN CONCENTRATION AND INSULIN RESISTANCE BY DIFFERENT CHILLI FOOD EATING FREQUENCIES

	Sometimes	*Often*	*Usually*	P *(trend)*
Men (*n*)[a]				
Ferritin	1	1.07 (0.92–1.24)	1.13 (0.94–1.35)	0.39
Model 1[a]	1	1.05 (0.90–1.23)	1.12 (0.92–1.33)	0.52
Model 2[b]	1	1.05 (0.90–1.23)	1.09 (0.91–1.31)	0.59
HOMA-IR	1	0.95 (0.82–1.11)	0.91 (0.76–1.09)	0.56
Model 1	1	0.97 (0.83–1.13)	0.94 (0.78–1.13)	0.76
Model 2	1	0.96 (0.83–1.12)	0.94 (0.78–1.13)	0.77
Women (*n*)[a]				
Ferritin	1	0.91 (0.78–1.05)	1.08 (0.90–1.29)	0.20
Model 1	1	1.01 (0.86–1.17)	1.12 (0.93–1.35)	0.45
Model 2	1	1.00 (0.86–1.17)	1.15 (0.95–1.38)	0.32
HOMA-IR	1	0.93 (0.80–1.08)	1.02 (0.85–1.22)	0.59
Model 1	1	0.95 (0.82–1.11)	1.02 (0.85–1.22)	0.74
Model 2	1	0.96 (0.82–1.11)	1.03 (0.86–1.23)	0.74

Data are presented as odds ratio (95% confidence interval).
[a]Model 1, odds ratio adjusted for age.
[b]Model 2, odds ratio adjusted for model 1 plus nationality, smoking use, alcohol consumption, and carbohydrate consumption.

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AUTHOR DISCLOSURE STATEMENT

No competing financial interests exist.

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