

Red Meat Intake Is Associated with Metabolic Syndrome and Plasma C-Reactive Protein Concentrations in Women^{1,2}

Leila Azadbakht* and Ahmad Esmailzadeh

Department of Nutrition, School of Public Health, Isfahan University of Medical Sciences, Isfahan, Iran; and Food Security and Nutrition Research Center, Isfahan University of Medical Sciences, Isfahan, Iran

Abstract

Although red meat consumption has been related to the prevalence of diabetes, few data are available showing the relation among red meat intake, inflammation, and metabolic syndrome. We aimed to identify the association between red meat intake, metabolic syndrome, and circulating concentrations of C-reactive protein (CRP) as a surrogate measure of inflammation. In a cross-sectional study of 482 Tehrani female teachers aged 40–60 y, we used a FFQ to assess red meat intake. Anthropometric measures, blood pressure, fasting plasma glucose, lipid profiles, and plasma CRP concentrations were evaluated according to standard methods. Metabolic syndrome was defined as recommended by National Cholesterol Education Program Adult Treatment Panel III guidelines. Red meat intake (mean \pm SEM) was 45.9 \pm 3.0 g/d. After statistically controlling for potential confounders, geometric mean plasma CRP concentrations across increasing quintile categories of red meat intake were 1.46, 1.66, 1.73, 1.89 \pm 1.89, and 2.03 mg/L (P -trend < 0.01). In the crude model, individuals in the top quintile of red meat intake had greater odds of having metabolic syndrome compared with those in the bottom quintile [odds ratio (OR): 2.33; 95% CI: 1.24, 4.38, P -trend < 0.01]. This association remained significant even after adjustment for potential confounders (OR, 2.15; CI, 1.18, 4.01; P -trend < 0.01). Adjustment for CRP did not affect this association (OR, 2.06; CI, 1.16, 3.98; P -trend < 0.01). In conclusion, increased red meat consumption is cross-sectionally associated with greater risk of metabolic syndrome and inflammation. Further prospective investigations will be needed to confirm this finding. *J. Nutr.* 139: 1–5, 2008.

Introduction

Metabolic syndrome is characterized by a variety of cardiovascular risk factors (1). Blood concentrations of inflammatory markers are also elevated in this syndrome (2,3). Intakes of certain foods, such as dairy, soy, fruit, and vegetables, were negatively associated with this syndrome and this association was positive with hydrogenated vegetable oil (4–8). However, few data are available regarding the association between red meat consumption and the prevalence of metabolic syndrome. Red meat intake has frequently been reported to increase the risk of colon, breast, and prostate cancers, heart disease, and diabetes (9–12). A dietary pattern heavily loaded with red meat is positively associated with the likelihood of having metabolic syndrome (13–15). Detrimental effects of saturated fat (11), animal protein (10), and high iron contents of red meat, particularly heme iron, might account for this association (12).

Plasma C-reactive protein (CRP)³ concentrations might be a factor through which diet would affect the development of metabolic syndrome (8,16). The plasma CRP concentration is also elevated in this syndrome (17). Increased lean red meat intake did not elevate markers of inflammation in humans (18), whereas adherence to dietary patterns with higher red meat intake has been significantly associated with markers of systemic inflammation, including CRP (14,19). The SFA content of red meat might explain these inconsistent findings to some extent (14). In this study, our primary aim was to assess the association of red meat consumption with prevalence of metabolic syndrome among female teachers aged 40–60 y living in Tehran. Our secondary aim was to search if this association is mediated through plasma concentrations of CRP.

Subjects and Methods

Detailed information about the study participants can be found in previous publications (15,19). The sample size of this cross-sectional study

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* To whom correspondence should be addressed. E-mail: azadbakht@hlth.mui.ac.ir.

³ Abbreviations used: CRP, C-reactive protein; HDL-C, HDL cholesterol; OR, odds ratio; TG, triacylglycerol.

was similar to our earlier studies (15,19–21). Only 4 women were currently smoking. Therefore, to avoid potential confounding from smoking, we excluded these women. Therefore, 482 subjects remained for the current study.

As described previously (19–21), usual dietary intakes were assessed using a validated 168-item semiquantitative FFQ. The red meat category was defined as the sum of processed meats (sausages and hamburger), red meats (beef, lamb), and organ meats (beef liver, kidney, and heart). Detailed information regarding anthropometric measurements, biochemical assessment, and other variables included in the current study can be found elsewhere (8). Additional covariate information regarding age, menopausal status, medical history, and current use of medications was obtained by using questionnaires (8,15,19–21). In the current study, obesity was defined as a BMI ≥ 30 . Metabolic syndrome was defined as recommended by the National Cholesterol Education Program Adult Treatment Panel III (ATP III) (22).

Statistical methods. The participants were categorized according to quintiles of red meat intake. We used 1-way ANOVA (with Tukey post hoc comparisons) and chi-square tests to identify significant differences in general characteristics across quintiles. Age-adjusted means for energy and macronutrient intakes and age- and energy-adjusted means for dietary variables were calculated by using ANCOVA with Bonferroni correction. Due to skewness in the distribution of CRP, we used logarithmically transformed values of this marker in all analyses. Geometric means for plasma concentrations of CRP across quintiles of red meat intake were calculated in a crude model and a 2nd model with adjustment for potential confounders, including age (continuous), physical activity (continuous), total energy intake (continuous), use of estrogen (yes or no), menopausal status (yes or no), and family history of diabetes or stroke (yes or no), intakes of dietary fiber and cholesterol (continuous), percent of energy from fat (continuous), fruit and vegetables (continuous), white meats and fish (continuous), dairy intake (continuous), partially hydrogenated and nonhydrogenated vegetable oils (continuous), and whole- and refined-grain intakes (continuous). BMI and dietary iron and protein intakes were considered as potential mediators in the relationship between red meat

intake and CRP concentrations. Therefore, additional exploratory models were constructed with separate inclusion of each of these mediators into the model.

We used multivariable logistic regression models to detect the association of red meat intake with metabolic syndrome and also its components. Again, 2 models were constructed: a crude model and an adjusted model that included age (continuous), physical activity (continuous), total energy intake (continuous), use of estrogen (yes or no), menopausal status (yes or no), family history of diabetes or stroke (yes or no), intakes of dietary fiber and cholesterol (continuous), percent of energy from fat (continuous), fruit and vegetables (continuous), white meats and fish (continuous), dairy intake (continuous), partially hydrogenated and nonhydrogenated vegetable oils (continuous), and whole- and refined-grain intakes (continuous) as potential confounders. Besides 3 mediating factors mentioned above, CRP was also considered as an additional mediating factor in the association of red meat intake with metabolic syndrome. Therefore, 4 exploratory models were constructed in this regard. In all models, the first quintile of red meat intake was considered as a reference. The Mantel-Haenszel extension test was performed to assess the overall trend of odds ratios (OR) across increasing quintiles. SPSS (version 9.05) was used for all statistical analyses. The significance level was set at 2-sided $P < 0.05$.

Results

Mean red meat intake in the study population was 45.9 g/d. Compared with subjects in the lowest quintile, those in the top quintile of red meat intake were younger, less physically active, and had higher BMI and waist circumference. Furthermore, metabolic syndrome and its components (high serum triacylglycerol (TG) concentrations, low serum HDL-cholesterol (HDL-C), and high systolic blood pressure) were more prevalent among those in the upper quintile than among those in the lowest quintile (Table 1).

TABLE 1 Characteristics of the study participants classified by quintiles of red meat intake¹

	Quintiles of red meat intake					P-value ²
	1	2	3	4	5	
<i>n</i>	97	98	97	97	97	
Red meat intake, g/d	<27.3	27.3–<35.1	35.1–<50.5	50.5–<63.7	≥ 63.7	
Age, y	52 \pm 5	51 \pm 6	51 \pm 6	50 \pm 7	48 \pm 5	<0.05
BMI, kg/m ²	26.9 \pm 3.4	27.2 \pm 3.2	27.3 \pm 3.6	27.7 \pm 3.6	28.4 \pm 4.1	<0.01
Waist girth, cm	88 \pm 10	88 \pm 10	90 \pm 10	91 \pm 11	94 \pm 11	<0.05
Physical activity, MET-h/wk	16.9 \pm 10.1	15.3 \pm 9.2	14.4 \pm 10.3	13.7 \pm 9.6	13.1 \pm 10.5	<0.05
Family history of diabetes, %	8	8	7	9	9	0.54
Family history of stroke, %	1	1	0	2	1	0.39
Current estrogen use, %	25	24	23	25	23	0.86
Postmenopausal, %	51	47	45	44	41	0.24
Obesity, ³ %	31	33	33	35	39	0.18
Metabolic syndrome, ⁴ %	22	27	29	33	39	<0.05
Components of metabolic syndrome, ⁴ %						
Abdominal obesity	61	59	64	67	65	0.55
High serum TG concentrations	46	54	57	62	71	<0.01
Low serum HDL-C concentrations	35	35	42	49	58	<0.01
Abnormal glucose homeostasis	7	8	7	8	9	0.46
High systolic blood pressure	13	19	24	29	34	<0.05
High diastolic blood pressure	22	20	25	24	27	0.61

¹ Values are means \pm SD or %.

² ANOVA for continuous and chi-square for categorical variables.

³ Obesity: BMI ≥ 30 kg/m².

⁴ Defined as the presence of ≥ 3 of the following components: 1) abdominal adiposity (waist circumference > 88 cm); 2) low serum HDL-C (< 1.29 mmol/L); 3) high serum TG concentrations (≥ 1.65 mmol/L); 4) elevated blood pressure ($\geq 130/85$ mm Hg); and 5) abnormal glucose homeostasis (≥ 6.05 mmol/L).

TABLE 2 Dietary intakes of participants classified by red meat intake quintile categories¹

	Quintiles of red meat intake					P-value ⁴
	1	2	3	4	5	
<i>n</i>	97	98	97	97	97	
Red meat intake, g/d	<27.3	27.3–<35.1	35.1–<50.5	50.5–<63.7	≥63.7	
Nutrients						
Total energy, ² kcal/d	2419 ± 28	2448 ± 27	2515 ± 27	2591 ± 19	2657 ± 21	<0.05
Total energy, ² kJ/d	10,111 ± 117	10,233 ± 113	10,513 ± 113	10,830 ± 79	11,106 ± 88	
Carbohydrate, ² % of total energy	62 ± 1	61 ± 1	60 ± 2	59 ± 1	56 ± 2	<0.05
Protein, ² % of total energy	11 ± 0.3	12 ± 0.3	12 ± 0.2	13 ± 0.4	14 ± 0.4	<0.05
Fat, ² % of total energy	27 ± 0.6	27 ± 0.7	28 ± 0.7	28 ± 0.8	30 ± 0.9	<0.05
Cholesterol, ³ mg/d	147 ± 9	164 ± 8	182 ± 9	198 ± 10	212 ± 11	<0.01
Dietary fiber, ³ g/d	19 ± 1	15 ± 1	16 ± 1	12 ± 1	11 ± 1	<0.05
Dietary iron, ³ mg/d	17 ± 1	16 ± 1	23 ± 1	31 ± 1	39 ± 1	<0.05
Foods, ³ g/d						
Fruit	278 ± 8	281 ± 8	216 ± 6	193 ± 7	158 ± 6	<0.05
Vegetables	255 ± 8	230 ± 7	193 ± 6	182 ± 5	169 ± 6	<0.05
White meat and fish	75 ± 6	67 ± 5	56 ± 4	42 ± 3	35 ± 4	<0.01
Whole grains	110 ± 2	127 ± 4	132 ± 3	102 ± 4	117 ± 5	0.21
Refined grains (including potato)	190 ± 2	209 ± 4	194 ± 3	206 ± 4	212 ± 6	0.08
Dairy	178 ± 3	194 ± 3	173 ± 4	190 ± 2	186 ± 5	0.37
Potato	28 ± 1	33 ± 1	30 ± 1	32 ± 1	26 ± 1	<0.05
Total vegetable oils	43 ± 2	47 ± 2	44 ± 3	52 ± 2	59 ± 3	<0.05

¹ Values are means ± SEM.² Adjusted for age.³ Adjusted for age and total energy intake.⁴ P-values obtained from ANCOVA.

Participants in the lowest quintile had lower intakes of energy, fat, protein, iron, cholesterol, and vegetable oils and higher intakes of dietary fiber, carbohydrates, fruits, vegetables, white meat, and fish (Table 2).

Red meat intake was directly related to plasma CRP concentrations (Table 3). After statistically controlling for potential confounders, geometric mean plasma CRP concentrations across increasing quintile categories of red meat intake were 1.48 ± 1.61 , 1.65 ± 2.22 , 1.77 ± 1.99 , 1.91 ± 1.89 , and 2.04 ± 1.80 mg/L (*P*-trend < 0.01). The percent differences of CRP concentration in the higher quintiles compared with the lowest quintile of red meat intake were 11, 19, 29, and 38% for the 2nd, 3rd, 4th, and 5th quintiles, respectively (*P*-trend < 0.01).

Red meat intake was significantly associated with metabolic syndrome (Table 4). This association remained significant even after adjustment for potential confounding variables. Further adjustment for CRP did not affect this association. Control for BMI attenuated the association but still remained significant. This association was also significant after adjusting for total dietary iron and for protein intakes.

Red meat intake was also associated with some components of metabolic syndrome. After controlling for potential confounders, participants in the top quintile of red meat intake were more likely to have low serum HDL-C (OR, 2.32; 95% CI, 1.33, 4.16), elevated serum TG concentrations (OR, 2.63; 95% CI, 1.42, 4.66), and high systolic blood pressure (OR, 3.38; 95% CI,

TABLE 3 Plasma CRP concentrations across quintile categories of red meat intake¹

	Quintiles of red meat intake					P-value ²
	1 (lowest)	2	3	4	5 (highest)	
<i>n</i>	97	98	97	97	97	
Red meat intake, g/d	<27.3	27.3–<35.1	35.1–<50.5	50.5–<63.7	≥63.7	
Plasma CRP, mg/L						
Model I ³	1.34 (1.04, 1.64)	1.59 (1.18–2.00)	1.75 (1.38–2.12)	1.99 (1.64–2.34)	2.19 (1.86, 2.52)	<0.01
Model II ⁴	1.48 (1.20, 1.76)	1.65 (1.26, 2.04)	1.77 (1.42, 2.12)	1.91 (1.58, 2.24)	2.04 (1.72, 2.36)	<0.01
Model II+BMI	1.59 (1.32, 1.72)	1.70 (1.32, 2.08)	1.77 (1.42, 2.12)	1.85 (1.53, 2.17)	1.97 (1.67, 2.27)	<0.05
Model II+ dietary iron intake	1.51 (1.22, 1.80)	1.67 (1.47, 1.87)	1.75 (1.40, 2.1)	1.87 (1.53, 2.21)	2.00 (1.69, 2.31)	<0.05
Model II+ protein intake	1.49 (1.21, 1.77)	1.64 (1.25, 2.03)	1.77 (1.42, 2.12)	1.90 (1.57, 2.23)	2.02 (1.71, 2.33)	<0.05

¹ Values are geometric mean (95% CI).² P-values obtained from ANCOVA.³ Model I: crude model.⁴ Model II: adjusted for age, physical activity, total energy intake, use of estrogen, menopausal status, family history of diabetes or stroke, and intakes of dietary fiber and cholesterol, percent of energy from fat, fruit, and vegetables, white meats and fish, dairy intake, partially hydrogenated and nonhydrogenated vegetable oils, whole- and refined-grain intakes.

TABLE 4 Multivariate-adjusted OR and 95% CI for metabolic syndrome across quintile categories of red meat intake^{1,2}

	Quintiles of the red meat intake					P-value ⁵
	1 (lowest)	2	3	4	5 (highest)	
<i>n</i>	97	98	97	97	97	
Red meat intake, g/d	<27.3	27.3–<35.1	35.1–<50.5	50.5–<63.7	≥63.7	
Model I ³	1.00	1.31 (0.68, 1.93) ⁴	1.47 (0.76, 2.82)	1.78 (0.94, 3.38)	2.33 (1.24, 4.38)	<0.01
Model II ⁴	1.00	1.17 (0.72, 1.79)	1.27 (0.80, 2.64)	1.57 (0.99, 3.08)	2.15 (1.18, 4.01)	<0.01
Model II + CRP	1.00	1.15 (0.79, 1.73)	1.22 (0.83, 2.63)	1.49 (0.97, 3.05)	2.06 (1.16, 3.98)	<0.01
Model II + BMI	1.00	1.15 (0.74, 1.75)	1.21 (0.84, 2.66)	1.48 (0.93, 2.98)	1.99 (1.09, 3.89)	<0.01
Model II + dietary iron intake	1.00	1.16 (0.71, 1.77)	1.25 (0.83, 2.60)	1.51 (0.96, 3.04)	2.13 (1.15, 3.97)	<0.01
Model II + protein intake	1.00	1.17 (0.70, 1.81)	1.24 (0.78, 2.67)	1.56 (0.97, 3.05)	2.10 (1.15, 3.96)	<0.01

¹ Values are OR (95% CI).

² Metabolic syndrome was defined as the presence of ≥3 of the following components: 1) abdominal adiposity (waist circumference > 88 cm); 2) low serum HDL-C (<1.29 mmol/L); 3) high serum TG concentrations (≥1.65 mmol/L); 4) elevated blood pressure (≥130/85 mm Hg); and 5) abnormal glucose homeostasis (≥6.05 mmol/L).

³ Model I: crude model.

⁴ Model II: controlled for age, physical activity, total energy intake, current estrogen use, menopausal status, family history of diabetes or stroke, intakes of dietary fiber and cholesterol, percent of energy from fat, fruit, and vegetables, white meats and fish, dairy, partially hydrogenated and nonhydrogenated vegetable oils, and whole- and refined-grains.

⁵ P-trend by using Mantel-Haenszel extension chi-square test.

1.57, 7.15). Additional adjustment for CRP slightly attenuated the associations, but all were still significant. This was also the case when BMI, dietary iron, or protein intakes were entered separately into the models (data not shown). Red meat intake, abdominal obesity, and impaired glucose homeostasis were not associated. Frequency of red meat intake was not associated with plasma CRP concentrations, metabolic syndrome, or its components.

Discussion

Our findings indicated a direct relationship between red meat intake, plasma CRP concentrations, and elevated risk of metabolic syndrome. These associations remained significant even after extensive adjustments were made for potential confounders. To our knowledge, this is the first study directly relating red meat intake to the risk of metabolic syndrome. However, the association between red meat intake and metabolic syndrome in the framework of dietary patterns has been reported previously (13–15). In a study of Japanese-Brazilians (14), men, not women, in the highest tertile of red meat intake had a 4.7 times greater risk for developing metabolic syndrome.

Inflammation has been reported to be involved in the pathogenesis of metabolic syndrome (23). CRP is a useful marker of inflammation *in vivo* (24). We are aware of only 1 study in this regard that has assessed lean red meat intake in relation to inflammation, with no significant correlation between these 2 (18). Our study indicated that high consumption of red meat is significantly associated with elevated levels of inflammation measured as plasma CRP concentration. This inconsistency might be explained by the lower content of SFA in lean red meat.

In this study, BMI was a mediator in the red meat-CRP association. Several factors might mediate the association of red meat intake with metabolic syndrome. CRP was a mediator in this association. BMI also was a mediator in this relationship. This association was not completely mediated through plasma CRP concentrations. However, plasma CRP concentrations were a step mediator in this regard, because after adjusting for the CRP concentration, this association was attenuated but still remained significant. However, CRP is also related to BMI.

Previous studies have suggested a significant relationship between red meat intake, type 2 diabetes, and cardiovascular risk factors (9–12). Cholesterol (14), iron (25), or SFA (14) content of red meat might explain these associations to some extent. Clinical studies have shown no significant effect of iron supplementation per day on plasma CRP concentrations (26,27). Heme iron has been shown to differently affect diabetes risk than non-heme iron. Moreover, heme iron from red meat has been suggested to differ from other sources in affecting human health, but the exact mechanism is not clear yet. Therefore, further evidence is required to clarify the possible role of iron in inflammation (27). To explore the potential mechanisms in the current study, we adjusted our statistical analyses for total iron and protein intakes separately. After these adjustments, the association of red meat intake, inflammation, and metabolic syndrome was attenuated but still significant. It must be kept in mind that total iron and protein intakes were adjusted and due to limitations in food analysis; we could not obtain data for dietary iron, particularly heme iron, and protein intakes from red meat. Therefore, more studies are required to clarify the potential mechanisms by which red meat intake affects inflammation and metabolic syndrome. We also categorized processed meat in the red meat category. Processed meats in Iran contain higher amounts of additives and sodium. These ingredients may also help explain the relationships we reached.

There are some limitations to this study that should be considered. This was a cross-sectional study, so the prospective association remains to be identified. Misclassification of the study participants, as a result of using a FFQ, was a concern in our study. Although we tried to control for known confounders, residual confounding cannot be excluded in our findings. Unfortunately, there is no information regarding the individual fatty acids in the Iranian Food Composition Table. We therefore could not analyze the effect of SFA content of the red meat in this association. Heme, non-heme iron, and vegetable or animal protein were not analyzed in our study. Therefore, we could not explain the potential mechanisms. Although we found a significant association between red meat intake, inflammation, and metabolic syndrome, reducing red meat intake among Iranian women must be recommended

cautiously due to the high prevalence of iron-deficiency anemia among Iranian women.

In conclusion, this study suggests that red meat intake is associated with higher risk of metabolic syndrome and higher concentrations of plasma CRP. Further prospective investigations are needed to confirm this finding.

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