Original Article

Dietary Glycemic Index, Glycemic Load and Blood Lipid Levels in Middle-Aged Japanese Men and Women

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Aims: This study investigated the association between dietary glycemic index (GI)/glycemic load (GL) and serum lipids in middle-aged Japanese men and women.

Methods: The study participants were employees of a metal products factory in Japan: 2,257 men and 1,598 women aged 35 years or older. Dietary GI and GL were assessed using a self-administered diet history questionnaire. Serum lipid levels, adjusted for age, body mass index, alcohol consumption, smoking, physical activity, menopause status, and dietary intake of total energy, saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, cholesterol and fiber, were compared among GI/GL quintiles for each gender.

Results: No significant associations were observed between GI and adjusted serum lipids in men or women. In contrast, GL was inversely associated with HDL-cholesterol in men and women (p for trend=0.001 for men and <0.001 for women), and positively associated with non-HDL-cholesterol (p for trend=0.010), LDL-cholesterol (p for trend=0.035) and triglycerides (p for trend=0.011) in women; however, alcohol drinking affected these associations; there was no association between GL and serum lipids in male nondrinkers and between GL and LDL-cholesterol in female nondrinkers.

Conclusion: GL was inversely associated with HDL-cholesterol and positively associated with non-HDL-cholesterol in Japanese women. These associations in men were not observed in nondrinkers. A high-GL diet for women may have an atherogenic effect through these serum lipid abnormalities.

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Key words; Glycemic index, Glycemic load, HDL-cholesterol, LDL-cholesterol, Japanese

Introduction

In 1981, Jenkins *et al.* noticed that foods with an equivalent carbohydrate content were associated with

a variable rise in postprandial glucose and reported glycemic indices (GIs) representing a numerical measure of hyperglycemic response to glucose load for 51 different kinds of food¹. Dietary GI can be calculated based on the GI for each food and the carbohydrate contribution of each food to the overall diet. Glycemic load (GL) is a measure that considers both dietary GI and the amount of carbohydrate intake². Recently, an association between dietary GI/GL and several diseases, including type 2 diabetes and cancer, has been

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reported³).

The association between GI and high-density lipoprotein cholesterol (HDL-C) was reported in previous studies involving Western and Asian populations⁴⁻¹⁰; however, some studies conducted in Western countries^{11, 12} have reported no significant association between GI/GL and HDL-C. In contrast, a recent U.S. study in middle-aged women reported not only a significant inverse association between GI and HDL-C but also a significant positive association between GI and low-density lipoprotein cholesterol (LDL-C)⁷. Reports on the association between GI/GL and serum lipids are limited, and the results are largely inconsistent.

Previous studies have frequently been conducted in the U.S. and Europe, and only a few reports are from Asian populations⁸⁻¹⁰ with higher rice intake and lower fat intake, which is significantly different, in terms of the foods contributing to dietary GI, to the intake of Western populations¹³. Studies from Japan are limited to women, and there are no studies available regarding middle-aged Japanese men. Furthermore, only one study from an Asian population examined the association between GI/GL and LDL-C, and there are no reports evaluating the association between GI/GL and non-HDL-C.

The present study was designed to determine the association between dietary GI/GL and serum lipids in a large population comprised of Japanese middle-aged men and women who had different dietary habits to Western populations.

Methods

Participants

The participants were 4,593 employees (2,813 men and 1,780 women), aged 35-years or older, of a manufacturer that produces zippers and aluminum sashes in Toyama Prefecture, Japan. In 2003, a regular mass health examination and a self-administered diet history questionnaire were conducted. Of the 4,593 employees, 4,327 (94%) (2,590 men and 1,737 women) underwent the health examination and responded to the diet survey. Employees with total calorie intake below 500 kcal or above 5,000 kcal ($n=16$), those with extremely high triglycerides (>400 mg/dL) and inadequately calculated LDL-C ($n=46$), and those on medication for hyperlipidemia ($n=136$), hypertension ($n=226$), and diabetes mellitus ($n=48$) were excluded. Thus, 3,855 participants (2,257 men and 1,598 women) were analyzed in this report.

Data Collection

Body height and weight were measured during a regular annual health examination conducted at the company in 2003. Body mass index (BMI) was calculated as the weight (kg) divided by the height squared (m^2). Total cholesterol, triglycerides, and HDL-C were measured using fasting blood samples. Total cholesterol and triglycerides were measured enzymatic ally, and HDL-C was measured directly. Quality control was conducted for the lipid measurements based on the Centers for Disease Control and Prevention / US Cholesterol Reference Method Laboratory Network. LDL-C was calculated using the Friedewald formula as described below¹⁴:

$$\text{LDL-C (mg/dL)} = \text{total cholesterol (mg/dL)} - \text{HDL-C (mg/dL)} - \text{triglycerides (mg/dL)} \times 0.2$$

Non-HDL cholesterol (non-HDL-C) was calculated as total cholesterol minus HDL-C.

Smoking status (presence or absence of a smoking habit), intensity of physical activity (none, mild, moderate or severe), and the menopause status for women were determined based on a health examination questionnaire.

Dietary Assessment

Dietary habits during the preceding month were assessed using a self-administered diet history questionnaire (DHQ)¹⁵. The DHQ was developed to estimate the dietary intake of macronutrients and micronutrients for epidemiological studies in Japan. A detailed description of the methods used for calculating dietary intake and the validity of the DHQ have been published previously^{13, 16-18}. Estimates of dietary intake for 147 food and beverage items, energy and nutrients were calculated using an ad hoc computer algorithm developed for the DHQ based on the Standard Tables of Food Composition in Japan.

Calculation of Dietary GI and GL

The GI of a food is defined as the 2-hour incremental area under the blood glucose response curve after consumption of a food portion containing a specific amount (usually 50 g) of available carbohydrate, divided by the corresponding area after consumption of a portion of a reference food (usually glucose or white bread) containing the same amount of available carbohydrate, and multiplied by 100 to be expressed as a percentage². We calculated dietary GI by multiplying the percentage contribution of each individual food to daily available carbohydrate intake by the GI value of the food and summed these products. Available carbohydrate was calculated as total carbohydrate

minus dietary fiber²⁾. We also calculated dietary GL by multiplying the dietary GI by the total amount of daily available carbohydrate intake (divided by 100). Of the 147 food and beverage items included in the DHQ, six (4.1%) are alcoholic beverages, eight (5.4%) contain no available carbohydrate and 63 (42.9%) contain less than 3.5 g available carbohydrate per serving. The calculation of dietary GI and GL was thus based on the remaining 70 items with GI values ranging from 16 to 91. A detailed description of the calculation of dietary GI and GL used in the present study as well as a table of GI values for each item have been published elsewhere^{9, 13)}.

Statistical Analysis

The gender-specific mean values of age, height, weight, BMI, and serum lipids (total cholesterol, triglycerides, HDL-C, LDL-C, and non-HDL-C) in each GI/GL quintile were determined. The mean serum lipid levels were calculated in each GI/GL quintile adjusted for age and BMI (model 2) or for multiple variables (i.e. age, BMI, alcohol consumption, smoking status, degree of habitual exercise, menopausal status (women), total energy intake, dietary intakes of saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), n-3 polyunsaturated fatty acids (PUFA), n-6 PUFA, dietary cholesterol and dietary fiber) (model 3) through analysis of covariance. For each variable, categorization and dummy variable adjustment were performed; three categories of alcohol consumption determined by the DHQ for men (nondrinker, consumed less than 20 g/day, consumed 20 g or more) and two categories of alcohol consumption for women (nondrinker or drinker), two categories of smoking status (current smoker or not), three categories for the degree of habitual exercise (no, light, moderate to strong), and five categories (quintile) for total energy intake (kcal/day), SFA (g/day), MUFA (g/day), n-3 PUFA (g/day), n-6 PUFA (g/day), dietary cholesterol (mg/day) and dietary fiber intake (g/day). Triglycerides were converted logarithmically for analysis. Linear trends with increasing levels of dietary GI and GL were tested by assigning each participant the median value for the category and modeling this value as a continuous variable. Similar analyses were conducted in subgroups based on drinking status (nondrinkers or drinkers) in both men and women, and in subgroups based on the menopausal status (pre- or postmenopause) in women. Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS version 17.0J; SPSS, Tokyo, Japan). $P < 0.05$ was considered significant.

Results

The characteristics of the study participants are shown in **Supplemental Table 1**. The mean ages were 47.4 years for men and 47.0 years for women. The mean BMIs were 23.3 kg/m² for men and 22.4 kg/m² for women. Thirty-nine percent of women were postmenopausal. The mean carbohydrate and fat intake (% of energy) were 57.8% and 21.4% for men and 59.2% and 25.8% for women, respectively. The mean dietary GIs were 69.3 for men and 68.0 for women. The mean dietary GLs (/1,000 kcal) were 88.2 for men and 89.2 for women. White rice was the largest contributor to dietary GI/GL (61.6% for men and 53.6% for women), followed by bread (6.9%), noodles (5.5%), and confectionery (5.1%) for men and confectionery (10.1%), bread (8.9%), and sugar (5.3%) for women (data shown in **Supplemental Table 2**).

In men and women, being in the higher GI and GL quintiles was associated with a significantly higher mean age, and no significant association between either GI or GL and BMI was observed (GL results are shown in **Table 1** and **2**). Higher GL was also associated with less alcohol, a lower habitual exercise rate, lower dietary energy intake, lower fatty acid intake, and higher carbohydrate intake.

GI was not significantly associated with serum lipids in men, and higher GI was associated with significantly higher triglycerides and non-HDL-C in women (data shown in **Supplemental Table 3**). When the mean serum lipid levels in the GI quintiles adjusted for multiple variables were determined, GI was significantly and inversely associated only with TG for men (p for trend = 0.029), and no significant association between GI and serum lipids was observed for women (data not tabulated).

The mean serum lipid levels in each GL quintile are shown in **Table 3** and **4**. In men (**Table 3**), higher GL was associated with significantly lower HDL-C and higher LDL-C and non-HDL-C in the univariate analyses (model 1) and age and BMI-adjusted models (model 2). When adjusted for multiple variables (model 3), higher GL was significantly associated only with lower HDL-C. The association between GL and LDL-C or non-HDL-C was not significant when drinking status was included in the model (data not tabulated), and also in the multivariate-adjusted model (model 3). In women (**Table 4**), higher GL was associated with significantly lower HDL-C, higher total cholesterol, triglycerides, LDL-C, and non-HDL-C (model 1). Higher GL was significantly associated with lower HDL-C and with higher triglycerides, LDL-C, and non-HDL-C in the age and BMI-

Table 1. Baseline characteristics of male study participants according to glycemic load quintiles

	Quintiles of dietary glycemic load					<i>p</i>
	Q1 (lowest) <i>n</i> =452 ≤73.0	Q2 <i>n</i> =451 73.1–83.4	Q3 <i>n</i> =452 83.5–91.9	Q4 <i>n</i> =451 92.0–103.3	Q5 (highest) <i>n</i> =451 ≥103.4	
Glycemic load (/1,000 kcal)						
Age (years)	46.7 ± 6.9	47.6 ± 6.8	47.0 ± 6.8	47.7 ± 6.9	47.9 ± 6.9	0.010
Body height (cm)	169.1 ± 6.1	169.7 ± 6.1	169.4 ± 5.9	168.9 ± 6.1	168.5 ± 6.5	0.041
Body weight (kg)	67.0 ± 9.4	67.5 ± 9.3	67.5 ± 9.8	65.9 ± 8.7	66.5 ± 9.8	0.076
Body mass index (kg/m ²)	23.3 ± 2.7	23.4 ± 2.8	23.4 ± 3.0	23.0 ± 2.8	23.3 ± 3.1	0.481
Current smoker (%)	58.8	53.7	54.2	47.0	54.1	0.011
Alcohol drinker (%)						<0.001
Nondrinkers	2.2	8.4	13.7	22.6	36.6	
Light drinkers (< 20 g/day)	20.4	36.8	45.4	50.3	50.3	
Moderate/heavy drinkers (≥20 g/day)	77.4	54.8	40.9	27.1	13.1	
Habitual exercise (%)						0.003
No	65.9	65.6	68.1	67.0	74.9	
Light	19.2	20.4	18.4	19.5	16.0	
Moderate/Strong	14.2	14.0	13.1	12.9	8.6	
Energy intake (kcal/day)	2,417 ± 625	2,268 ± 554	2,191 ± 582	2,103 ± 548	2,024 ± 644	<0.001
Carbohydrate intake (g/day)	278.5 ± 72.6	303.1 ± 75.7	316.9 ± 87.5	326.1 ± 87.1	350.6 ± 113.6	<0.001
Fat intake (g/day)	69.3 ± 30.9	60.0 ± 21.9	54.1 ± 20.5	46.8 ± 16.2	35.2 ± 14.9	<0.001
Protein intake (g/day)	77.5 ± 27.1	71.0 ± 23.2	65.5 ± 21.3	61.1 ± 17.6	52.5 ± 18.4	<0.001
Carbohydrate intake (%Energy)	46.3 ± 5.6	53.4 ± 3.1	57.8 ± 2.7	62.0 ± 2.9	69.3 ± 4.5	<0.001
Fat intake (%Energy)	25.5 ± 7.5	23.6 ± 5.7	22.0 ± 5.2	19.9 ± 4.4	15.6 ± 4.3	<0.001
SFA (g/day)	17.3 ± 8.2	15.1 ± 6.0	13.9 ± 5.8	12.1 ± 4.5	9.2 ± 4.3	<0.001
MUFA (g/day)	25.6 ± 12.4	21.7 ± 8.3	19.4 ± 7.5	16.5 ± 6.2	12.1 ± 5.5	<0.001
n3PUFA (g/day)	3.6 ± 1.8	3.0 ± 1.3	2.6 ± 1.1	2.3 ± 0.9	1.7 ± 0.8	<0.001
n6PUFA (g/day)	13.6 ± 6.0	11.9 ± 4.3	10.6 ± 3.8	9.3 ± 3.3	7.3 ± 3.0	<0.001
Dietary cholesterol (mg/day)	353.2 ± 171.1	301.4 ± 140.6	259.2 ± 124.6	226.5 ± 106.8	158.6 ± 94.2	<0.001
Fiber intake (g/day)	12.3 ± 4.9	11.8 ± 4.5	11.2 ± 4.2	10.6 ± 3.9	9.6 ± 4.0	<0.001
Dietary glycemic index	67.1 ± 4.5	68.4 ± 3.6	69.1 ± 3.4	70.1 ± 3.2	71.5 ± 3.1	<0.001
Glycemic index-white rice (%)	52.8 ± 23.7	58.0 ± 20.6	60.3 ± 20.1	65.1 ± 19.6	71.3 ± 19.6	<0.001
Glycemic index-bread (%)	7.1 ± 8.4	7.8 ± 8.3	7.4 ± 8.3	6.6 ± 7.9	5.4 ± 7.7	<0.001
Glycemic index-noodles (%)	7.2 ± 7.4	5.9 ± 5.1	5.5 ± 5.1	4.6 ± 4.9	4.0 ± 4.4	<0.001
Glycemic index-confectioneries (%)	6.1 ± 5.7	5.4 ± 4.7	5.0 ± 4.0	4.7 ± 3.8	3.2 ± 3.9	<0.001
Glycemic index-sugar (%)	6.1 ± 4.0	5.2 ± 3.5	5.0 ± 3.5	4.3 ± 3.2	3.5 ± 2.7	<0.001
White rice intake (g/day)	285.9 ± 148.4	359.4 ± 148.1	403.6 ± 159.7	463.4 ± 175.1	579.8 ± 244.6	<0.001

Values are the mean ± standard deviation or %.

adjusted model (model 2) and also in the multivariate-adjusted model (model 3).

Because drinking status had a large effect on the multivariate-adjusted model results, we analyzed the subgroups separately based on drinking status in men and women. Compared to nondrinkers, dietary GL and carbohydrate intake were lower in both male and female drinkers, while fat intake was higher in male drinkers but lower in female drinkers (data in **Supplement Table 4**). In male nondrinkers (*n*=377), no

associations between GL and serum lipid levels were observed (**Table 5**). In male drinkers (*n*=1,880) the associations between GL and serum lipid levels were similar to those of all men. In female nondrinkers (*n*=949), higher GL was associated with significantly lower HDL-C, higher triglycerides, and higher non-HDL-C, but was not associated with LDL-C (**Table 6**). In female drinkers (*n*=649), higher GL was associated with significantly lower HDL-C, higher non-HDL-C and higher LDL-C.

Table 2. Baseline characteristics of female study participants according to glycemic load quintiles

	Quintiles of dietary glycemic load					<i>p</i>
	Q1 (lowest) <i>n</i> = 320 ≤76.8	Q2 <i>n</i> = 320 76.9–84.8	Q3 <i>n</i> = 319 84.9–92.0	Q4 <i>n</i> = 320 92.1–101.3	Q5 (highest) <i>n</i> = 319 ≥101.4	
Glycemic load (/1,000 kcal)						
Age (years)	45.4 ± 6.4	45.8 ± 6.6	46.9 ± 6.9	47.4 ± 6.8	49.5 ± 6.3	<0.001
Body height (cm)	156.8 ± 5.4	156.4 ± 5.5	156.0 ± 5.2	156.0 ± 5.7	154.4 ± 5.7	<0.001
Body weight (kg)	55.1 ± 8.7	54.6 ± 8.8	54.5 ± 8.3	54.8 ± 8.8	53.5 ± 8.9	0.044
Body mass index (kg/m ²)	22.4 ± 3.4	22.3 ± 3.4	22.3 ± 3.3	22.5 ± 3.4	22.4 ± 3.5	0.668
Menopause (%)	31.3	31.3	39.5	41.9	53.0	<0.001
Current smoker (%)	4.7	4.7	3.1	1.6	3.1	0.160
Alcohol drinker (%)						<0.001
Nondrinkers	41.6	50.9	58.6	67.2	78.7	
Light drinkers (<20 g/day)	50.6	47.8	39.5	31.3	21.0	
Moderate/heavy drinkers (≥20 g/day)	7.8	1.3	1.9	1.6	0.3	
Habitual exercise (%)						0.007
No	73.4	75.9	80.6	81.9	85.6	
Light	13.4	12.2	11.6	8.8	6.6	
Moderate/Strong	12.5	11.9	7.2	9.1	7.5	
Energy intake (kcal/day)	2,112 ± 614	1,977 ± 452	1,846 ± 407	1,744 ± 471	1,568 ± 461	<0.001
Carbohydrate intake (g/day)	265.6 ± 78.4	274.9 ± 65.2	271.2 ± 60.9	273.1 ± 75.5	268.0 ± 80.0	0.830
Fat intake (g/day)	76.5 ± 27.4	63.5 ± 16.2	54.1 ± 15.1	44.7 ± 13.7	32.5 ± 12.2	<0.001
Protein intake (g/day)	75.4 ± 23.2	67.0 ± 17.5	59.5 ± 13.6	54.2 ± 15.2	43.2 ± 14.3	<0.001
Carbohydrate intake (%Energy)	50.3 ± 4.2	55.5 ± 2.5	58.8 ± 2.5	62.6 ± 2.8	68.4 ± 4.2	<0.001
Fat intake (%Energy)	32.3 ± 4.9	28.8 ± 3.2	26.1 ± 3.2	22.9 ± 2.9	18.4 ± 3.7	<0.001
SFA (g/day)	19.8 ± 7.8	17.0 ± 5.3	14.4 ± 4.9	11.8 ± 4.2	8.6 ± 3.8	<0.001
MUFA (g/day)	27.6 ± 10.9	22.2 ± 6.0	18.8 ± 5.6	15.1 ± 4.9	10.9 ± 4.2	<0.001
n3PUFA (g/day)	3.7 ± 1.6	2.9 ± 1.0	2.5 ± 0.9	2.1 ± 0.8	1.5 ± 0.6	<0.001
n6PUFA (g/day)	14.7 ± 5.5	12.1 ± 3.3	10.4 ± 2.9	8.6 ± 2.6	6.5 ± 2.2	<0.001
Dietary cholesterol (mg/day)	340.6 ± 149.2	296.3 ± 120.4	236.8 ± 82.3	200.1 ± 80.2	137.9 ± 80.5	<0.001
Fiber intake (g/day)	14.1 ± 5.4	13.1 ± 4.3	12.0 ± 3.7	11.0 ± 3.7	9.0 ± 3.4	<0.001
Dietary glycemic index	65.3 ± 4.0	67.1 ± 3.3	68.1 ± 3.0	68.7 ± 3.1	70.6 ± 3.0	<0.001
Glycemic index-white rice (%)	41.3 ± 21.1	48.7 ± 18.1	54.0 ± 18.6	58.2 ± 17.8	65.5 ± 17.4	<0.001
Glycemic index-bread (%)	9.7 ± 7.9	9.9 ± 8.0	9.0 ± 8.1	8.7 ± 9.0	6.7 ± 7.7	<0.001
Glycemic index-noodles (%)	5.5 ± 5.0	4.8 ± 4.7	4.0 ± 3.9	4.3 ± 4.3	3.4 ± 4.2	<0.001
Glycemic index-confectioneries (%)	11.9 ± 7.9	11.1 ± 6.3	9.8 ± 6.1	8.4 ± 6.0	7.5 ± 6.0	<0.001
Glycemic index-sugar (%)	6.2 ± 3.6	5.7 ± 3.4	5.1 ± 3.5	5.0 ± 3.8	4.1 ± 2.6	<0.001
White rice intake (g/day)	212.8 ± 119.0	273.6 ± 115.3	305.7 ± 111.3	337.5 ± 123.2	392.3 ± 136.1	<0.001

Values are the mean ± standard deviation or %.

Women were analyzed separately in subgroups based on the menopausal status (pre- or postmenopause, data shown in **Supplement Table 5**). Although no difference in GI was observed between pre- and post-menopause, postmenopausal women were associated with a higher GL than premenopausal women, higher carbohydrate intake, and lower fat intake. Postmenopausal women showed higher mean serum lipids than premenopausal women. The associations between

GL and serum lipid levels were similar between pre- and postmenopausal women.

Discussion

The present study investigated the association between serum lipids and dietary GI/GL in a large population of Japanese middle-aged men and women. The results indicated a significant inverse association

Table 3. Means lipid levels according to glycemic load quintiles for men

	Quintiles of dietary glycemic load					<i>p</i> for trend
	Q1 (lowest) <i>n</i> =452 ≤73.0	Q2 <i>n</i> =451 73.1–83.4	Q3 <i>n</i> =452 83.5–91.9	Q4 <i>n</i> =451 92.0–103.3	Q5 (highest) <i>n</i> =451 ≥103.4	
Glycemic load (/1,000kcal)						
Total cholesterol (mg/dL)						
Model 1 (no adjustment)	204.7 ± 1.6	205.0 ± 1.6	205.1 ± 1.6	208.1 ± 1.5	207.7 ± 1.5	0.067
Model 2 (adjusted for age and BMI)	204.8 ± 1.5	204.7 ± 1.5	204.9 ± 1.5	208.6 ± 1.5	207.5 ± 1.5	0.066
Model 3 (adjusted for multivariate)	207.4 ± 1.8	205.9 ± 1.6	205.2 ± 1.5	207.4 ± 1.6	204.6 ± 2.0	0.515
Triglycerides (mg/dL)*						
Model 1 (no adjustment)	99.1 (94.1–104.4)	94.0 (89.4–99.0)	104.5 (99.6–109.6)	94.8 (90.3–99.5)	98.3 (93.7–103.2)	0.884
Model 2 (adjusted for age and BMI)	100.0 (95.5–104.7)	94.6 (90.4–99.1)	104.7 (100.0–109.7)	97.7 (93.3–102.3)	99.3 (94.8–104.0)	0.882
Model 3 (adjusted for multivariate)	99.8 (94.4–105.4)	94.6 (90.1–99.3)	104.0 (99.3–108.9)	97.1 (92.5–101.8)	95.3 (89.8–101.1)	0.508
HDL cholesterol (mg/dL)						
Model 1 (no adjustment)	62.2 ± 0.7	59.7 ± 0.7	57.4 ± 0.7	57.9 ± 0.6	55.8 ± 0.6	<0.001
Model 2 (adjusted for age and BMI)	62.3 ± 0.6	59.8 ± 0.6	57.7 ± 0.6	57.4 ± 0.6	55.8 ± 0.6	<0.001
Model 3 (adjusted for multivariate)	61.0 ± 0.7	59.4 ± 0.6	57.8 ± 0.6	58.1 ± 0.6	56.8 ± 0.8	0.001
LDL cholesterol (mg/dL)						
Model 1 (no adjustment)	118.9 ± 1.5	123.0 ± 1.5	123.5 ± 1.5	128.1 ± 1.4	129.0 ± 1.4	<0.001
Model 2 (adjusted for age and BMI)	119.0 ± 1.4	122.7 ± 1.4	123.2 ± 1.4	128.7 ± 1.4	128.8 ± 1.4	<0.001
Model 3 (adjusted for multivariate)	122.7 ± 1.7	124.1 ± 1.5	123.2 ± 1.4	126.8 ± 1.5	125.7 ± 1.8	0.194
Non-HDL cholesterol (mg/dL)						
Model 1 (no adjustment)	142.4 ± 1.7	145.3 ± 1.7	147.7 ± 1.6	150.1 ± 1.6	151.9 ± 1.6	<0.001
Model 2 (adjusted for age and BMI)	142.5 ± 1.5	144.9 ± 1.5	147.2 ± 1.5	151.1 ± 1.5	151.7 ± 1.5	<0.001
Model 3 (adjusted for multivariate)	146.5 ± 1.8	146.5 ± 1.6	147.4 ± 1.5	149.3 ± 1.6	147.8 ± 2.0	0.471

Values are the mean ± standard error.

*Values are geometric means (95% confidence interval).

Model 1, no adjustment; Model 2, adjusted for age and body mass index; Model 3, adjusted for age, body mass index, smoking, alcohol drinking, habitual exercise, dietary total energy, SFA, MUFA, n-3 PUFA, n-6 PUFA, dietary cholesterol, and dietary fiber intake.

between GL and HDL-C in both men and women. Furthermore, GL was significantly and positively associated with non-HDL-C and LDL-C in women. Previous studies on the association between GI/GL and serum lipids have been reported, primarily in the U.S. and Europe^{4-7, 11}; but relatively few are available from Asian countries where there is higher rice intake and lower fat intake.

Dietary GI/GL is inversely associated with HDL-C⁴⁻¹⁰ and is positively associated with LDL-C⁷; however, some reports show no association between dietary GI/GL and HDL-C^{11, 12} or LDL-C^{4, 9, 19}; the results on the association between GI/GL and serum lipids are therefore inconsistent. In the present study, the multivariate-adjusted models indicated that GL was significantly associated with HDL-C, LDL-C, and non-HDL-C in women but was associated only with HDL-C in men. Differences in these results are probably due to different characteristics, such as age, gender and ethnicity, and the life styles of the participants.

The results from the Third National Health and Nutrition Examination Survey in the U.S. demonstrated an inverse association between GL and HDL-C in men, but not in women¹². That study included relatively young and largely premenopausal women, and the authors postulated that the effect of sex hormones in women could explain such gender differences; however, no previous study has evaluated the effects of sex hormones on GI/GL-serum lipid associations. Thus, we analyzed using the menopausal status in women. Although the mean LDL-C and non-HDL-C values were significantly higher in postmenopausal women than in premenopausal women, the associations between GL and serum lipid levels were similar. These results indicated that differences in sex hormones cannot fully explain the gender difference.

Differences in lifestyle and dietary factors may also have influenced the gender results. For example, alcohol intake can affect not only serum lipid levels but also food intake patterns, and alcohol consumption was more common in men than in women. In

Table 4. Means lipid levels according to glycemic load quintiles for women

	Quintiles of dietary glycemic load					<i>p</i> for trend
	Q1 (lowest) <i>n</i> = 320 ≤76.8	Q2 <i>n</i> = 320 76.9–84.8	Q3 <i>n</i> = 319 84.9–92.0	Q4 <i>n</i> = 320 92.1–101.3	Q5 (highest) <i>n</i> = 319 ≥101.4	
Glycemic load (/1,000kcal)						
Total cholesterol (mg/dL)						
Model 1 (no adjustment)	204.8 ± 1.9	207.3 ± 1.8	208.6 ± 1.9	213.1 ± 1.9	214.0 ± 1.9	<0.001
Model 2 (adjusted for age and BMI)	207.5 ± 1.7	209.4 ± 1.7	208.7 ± 1.7	212.2 ± 1.7	209.8 ± 1.8	0.214
Model 3 (adjusted for multivariate)	207.1 ± 2.2	209.9 ± 1.9	208.6 ± 1.8	212.4 ± 1.9	209.6 ± 2.5	0.398
Triglycerides (mg/dL)*						
Model 1 (no adjustment)	62.0 (58.9–65.3)	63.3 (60.2–66.5)	66.6 (63.3–70.0)	67.8 (64.3–71.4)	72.8 (69.1–76.7)	<0.001
Model 2 (adjusted for age and BMI)	64.0 (61.0–67.1)	65.3 (62.3–68.5)	67.6 (64.5–70.9)	67.8 (64.6–71.0)	71.3 (67.9–74.8)	0.003
Model 3 (adjusted for multivariate)	62.5 (58.9–66.4)	63.8 (60.5–67.3)	66.5 (63.3–69.9)	68.2 (64.8–71.9)	71.3 (66.6–76.2)	0.011
HDL cholesterol (mg/dL)						
Model 1 (no adjustment)	69.9 ± 0.9	70.1 ± 0.8	66.8 ± 0.8	68.1 ± 0.8	65.4 ± 0.8	<0.001
Model 2 (adjusted for age and BMI)	69.8 ± 0.8	69.9 ± 0.8	66.7 ± 0.8	68.3 ± 0.8	65.6 ± 0.8	<0.001
Model 3 (adjusted for multivariate)	70.7 ± 1.0	70.6 ± 0.9	67.0 ± 0.8	67.7 ± 0.8	64.3 ± 1.1	<0.001
LDL cholesterol (mg/dL)						
Model 1 (no adjustment)	120.8 ± 1.8	122.9 ± 1.6	126.7 ± 1.7	129.5 ± 1.8	131.9 ± 1.8	<0.001
Model 2 (adjusted for age and BMI)	123.4 ± 1.6	124.9 ± 1.6	126.9 ± 1.6	128.7 ± 1.6	128.0 ± 1.6	0.013
Model 3 (adjusted for multivariate)	122.3 ± 2.0	125.0 ± 1.8	126.6 ± 1.6	129.1 ± 1.7	129.0 ± 2.2	0.035
Non-HDL cholesterol (mg/dL)						
Model 1 (no adjustment)	135.0 ± 1.9	137.2 ± 1.8	141.8 ± 1.9	144.9 ± 2.0	148.5 ± 1.9	<0.001
Model 2 (adjusted for age and BMI)	137.8 ± 1.7	139.5 ± 1.7	142.0 ± 1.7	143.9 ± 1.7	144.2 ± 1.7	0.002
Model 3 (adjusted for multivariate)	136.4 ± 2.1	139.3 ± 1.9	141.6 ± 1.8	144.7 ± 1.9	145.4 ± 2.4	0.010

Values are the mean ± standard error.

*Values are geometric means (95% confidence interval).

Model 1, no adjustment; Model 2, adjusted for age and body mass index; Model 3, adjusted for age, body mass index, menopause status, smoking, alcohol drinking, habitual exercise, dietary total energy, SFA, MUFA, n-3 PUFA, n-6 PUFA, dietary cholesterol, and dietary fiber intake.

the model adjusted for alcohol consumption, significant associations between GL and both LDL-C and non-HDL-C were observed for women but not for men. GL was associated with non-HDL-C in female nondrinkers, suggesting that the association between GL and non-HDL-C might be independent of alcohol consumption. Although there were no significant associations in male nondrinkers, the sample size may have been too small for an association to be apparent. On the other hand, a gender difference was observed in the influence of alcohol drinking on food intake patterns. A lower carbohydrate intake was observed in drinkers than in nondrinkers, a tendency that was more pronounced in men, and fat intake was higher in male nondrinkers, whereas in women it was higher in drinkers. We should consider these differences in lifestyle and food intake patterns when evaluating the association between GI/GL and diseases and gender differences.

Non-HDL-C represents a measure of serum lipids, which is a better predictor of the development of

cardiovascular disease^{20–23}). A previous study showed that GI was significantly associated with the total cholesterol/HDL-C ratio¹⁹) or LDL-C/HDL-C ratio⁷); however, no studies have evaluated the association between GI/GL and non-HDL-C. In our study, a gender difference was observed in the association between GL and non-HDL-C; GL was positively associated with non-HDL-C only in women. A high GL diet in women may lead to the development of atherosclerosis, because it is associated with low HDL-C and high non-HDL-C, which are closely related to atherogenesis.

A potential mechanism for the association between a high GL diet and serum lipids is abnormal lipid metabolism due to postprandial hyperglycemia and insulin resistance. Reducing postprandial hyperglycemia with an alpha-glucosidase inhibitor may increase lipoprotein lipase mass and prevent carotid atherosclerosis in patients with type 2 diabetes²⁴); however, the present study did not determine measures related to insulin resistance, or postprandial

Table 5. Multivariate-adjusted mean lipid levels according to glycemic load quintiles for male nondrinkers ($n=377$) and drinkers ($n=1,880$)

	Quintiles of dietary glycemic load					<i>p</i> for trend
	Q1 (lowest)	Q2	Q3	Q4	Q5 (highest)	
Nondrinkers	$n=76$ ≤ 87.4	$n=76$ 87.5–97.0	$n=76$ 97.1–105.0	$n=74$ 105.1–115.0	$n=75$ ≥ 115.1	
Total cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	203.7 $\pm$ 3.4	204.6 $\pm$ 3.4	217.6 $\pm$ 3.4	207.7 $\pm$ 3.5	210.9 $\pm$ 3.4	0.125
Model 3 (adjusted for multivariate)	208.0 $\pm$ 4.7	206.0 $\pm$ 4.0	218.3 $\pm$ 3.6	205.4 $\pm$ 3.9	206.8 $\pm$ 5.1	0.976
Triglycerides (mg/dL)*						
Model 2 (adjusted for age and BMI)	94.0 (84.0–105.2)	97.3 (87.0–108.8)	102.1 (91.2–114.2)	110.1 (98.2–123.3)	101.3 (90.4–113.4)	0.155
Model 3 (adjusted for multivariate)	99.9 (85.3–116.9)	101.2 (88.6–115.6)	99.8 (88.6–112.4)	107.1 (94.0–122.0)	96.2 (81.1–114.0)	0.909
HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	53.4 $\pm$ 1.3	54.3 $\pm$ 1.3	53.9 $\pm$ 1.3	51.6 $\pm$ 1.3	53.2 $\pm$ 1.3	0.504
Model 3 (adjusted for multivariate)	52.1 $\pm$ 1.7	52.2 $\pm$ 1.5	53.2 $\pm$ 1.3	52.5 $\pm$ 1.4	56.5 $\pm$ 1.9	0.211
LDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	128.4 $\pm$ 3.2	127.5 $\pm$ 3.2	139.8 $\pm$ 3.2	130.1 $\pm$ 3.2	133.8 $\pm$ 3.2	0.204
Model 3 (adjusted for multivariate)	132.3 $\pm$ 4.5	130.6 $\pm$ 3.8	141.9 $\pm$ 3.4	127.3 $\pm$ 3.7	127.2 $\pm$ 4.8	0.595
Non-HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	150.4 $\pm$ 3.4	150.4 $\pm$ 3.4	163.7 $\pm$ 3.4	156.1 $\pm$ 3.5	157.7 $\pm$ 3.5	0.076
Model 3 (adjusted for multivariate)	155.9 $\pm$ 4.7	153.8 $\pm$ 4.0	165.2 $\pm$ 3.6	152.9 $\pm$ 3.9	150.3 $\pm$ 5.1	0.628
Drinkers	$n=380$ ≤ 70.8	$n=377$ 70.9–80.8	$n=371$ 80.9–89.0	$n=377$ 89.1–99.3	$n=375$ ≥ 99.4	<i>p</i> for trend
Total cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	204.7 $\pm$ 1.7	204.9 $\pm$ 1.7	205.0 $\pm$ 1.7	206.8 $\pm$ 1.7	206.2 $\pm$ 1.7	0.379
Model 3 (adjusted for multivariate)	206.5 $\pm$ 1.9	205.4 $\pm$ 1.8	205.2 $\pm$ 1.7	206.3 $\pm$ 1.7	204.2 $\pm$ 2.1	0.572
Triglycerides (mg/dL)*						
Model 2 (adjusted for age and BMI)	101.3 (96.3–106.5)	91.7 (87.2–96.4)	102.3 (97.3–107.7)	99.3 (94.4–104.4)	93.7 (89.1–98.6)	0.239
Model 3 (adjusted for multivariate)	100.9 (95.3–106.9)	91.8 (87.1–96.8)	102.6 (97.5–108.0)	100.3 (95.3–105.7)	92.7 (87.1–98.6)	0.333
HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	62.1 $\pm$ 0.7	61.3 $\pm$ 0.7	58.3 $\pm$ 0.7	59.1 $\pm$ 0.7	57.5 $\pm$ 0.7	<0.001
Model 3 (adjusted for multivariate)	61.5 $\pm$ 0.8	61.3 $\pm$ 0.7	58.5 $\pm$ 0.7	59.1 $\pm$ 0.7	57.9 $\pm$ 0.8	0.002
LDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	118.6 $\pm$ 1.6	121.8 $\pm$ 1.6	122.8 $\pm$ 1.6	124.7 $\pm$ 1.6	127.1 $\pm$ 1.6	<0.001
Model 3 (adjusted for multivariate)	121.0 $\pm$ 1.8	122.4 $\pm$ 1.6	122.7 $\pm$ 1.6	124.0 $\pm$ 1.6	124.9 $\pm$ 1.9	0.170
Non-HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	142.7 $\pm$ 1.7	143.6 $\pm$ 1.7	146.7 $\pm$ 1.7	147.7 $\pm$ 1.7	148.7 $\pm$ 1.7	0.003
Model 3 (adjusted for multivariate)	145.0 $\pm$ 1.9	144.1 $\pm$ 1.8	146.7 $\pm$ 1.7	147.2 $\pm$ 1.7	146.2 $\pm$ 2.1	0.503

Values are the mean $\pm$ standard error.

*Values are geometric means (95% confidence interval).

Model 2, adjusted for age and body mass index; Model 3, adjusted for age, body mass index, smoking, habitual exercise, dietary total energy, SFA, MUFA, n-3 PUFA, n-6 PUFA, dietary cholesterol, and dietary fiber intake.

hyperglycemia. Further investigation into the potential mechanism is warranted.

The strengths of this study include a large Japanese population, which is significantly different in terms of the foods contributing to dietary GI from a U.S. or European population, and this is the first such study to include Japanese men. Additionally, all serum

lipid data were measured in a standardized way using fasting blood samples, and GI and GL were calculated using responses to a validated questionnaire. The limitations of this study include the factors that the study population was exclusive, because the participants were employed by a company in a rural city, and that the study was cross-sectional. Given that there are

Table 6. Multivariate-adjusted mean lipid levels according to glycemic load quintiles for female nondrinkers ($n=949$) and drinkers ($n=649$)

	Quintiles of dietary glycemic load					<i>p</i> for trend
	Q1 (lowest)	Q2	Q3	Q4	Q5 (highest)	
Nondrinkers	$n=192$ ≤ 80.1	$n=188$ 80.2–87.6	$n=192$ 87.7–95.5	$n=189$ 95.6–104.1	$n=188$ ≥ 104.2	
Total cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	206.9 $\pm$ 2.2	213.7 $\pm$ 2.3	208.5 $\pm$ 2.2	214.2 $\pm$ 2.2	209.8 $\pm$ 2.3	0.379
Model 3 (adjusted for multivariate)	206.4 $\pm$ 2.9	214.0 $\pm$ 2.6	208.5 $\pm$ 2.4	215.1 $\pm$ 2.5	209.0 $\pm$ 3.3	0.460
Triglycerides (mg/dL)*						
Model 2 (adjusted for age and BMI)	62.6 (58.8–66.6)	68.8 (64.6–73.2)	65.0 (61.2–69.2)	68.7 (64.5–73.1)	72.7 (68.3–77.5)	0.003
Model 3 (adjusted for multivariate)	59.5 (54.8–64.6)	66.3 (61.7–71.3)	64.6 (60.5–69.0)	71.7 (66.9–76.9)	76.6 (69.7–84.1)	0.001
HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	68.2 $\pm$ 1.0	68.1 $\pm$ 1.0	66.2 $\pm$ 1.0	66.8 $\pm$ 1.0	64.2 $\pm$ 1.0	0.003
Model 3 (adjusted for multivariate)	69.8 $\pm$ 1.3	69.1 $\pm$ 1.1	66.3 $\pm$ 1.0	65.6 $\pm$ 1.1	62.6 $\pm$ 1.5	0.002
LDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	124.3 $\pm$ 2.0	129.9 $\pm$ 2.1	127.5 $\pm$ 2.0	132.1 $\pm$ 2.1	128.8 $\pm$ 2.1	0.095
Model 3 (adjusted for multivariate)	123.1 $\pm$ 2.7	129.8 $\pm$ 2.4	127.4 $\pm$ 2.2	133.4 $\pm$ 2.3	128.8 $\pm$ 3.1	0.137
Non-HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	138.7 $\pm$ 2.2	145.6 $\pm$ 2.2	142.3 $\pm$ 2.2	147.4 $\pm$ 2.2	145.6 $\pm$ 2.2	0.025
Model 3 (adjusted for multivariate)	136.6 $\pm$ 2.8	144.9 $\pm$ 2.5	142.1 $\pm$ 2.3	149.5 $\pm$ 2.4	146.5 $\pm$ 3.2	0.029
Drinkers	$n=132$ ≤ 73.2	$n=129$ 73.3–80.7	$n=132$ 80.8–87.0	$n=130$ 87.1–95.2	$n=126$ ≥ 95.3	<i>p</i> for trend
Total cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	205.3 $\pm$ 2.7	207.8 $\pm$ 2.8	206.4 $\pm$ 2.7	208.2 $\pm$ 2.8	212.7 $\pm$ 2.8	0.072
Model 3 (adjusted for multivariate)	203.3 $\pm$ 3.2	208.0 $\pm$ 3.0	205.0 $\pm$ 2.9	210.6 $\pm$ 3.0	213.5 $\pm$ 3.7	0.077
Triglycerides (mg/dL)*						
Model 2 (adjusted for age and BMI)	63.1 (58.7–67.9)	63.4 (58.9–68.3)	64.9 (60.4–69.9)	64.5 (59.9–69.4)	68.7 (63.7–74.0)	0.107
Model 3 (adjusted for multivariate)	63.5 (58.2–69.1)	63.2 (58.3–68.5)	64.8 (60.0–69.9)	65.2 (60.2–70.6)	68.0 (61.7–75.0)	0.343
HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	72.3 $\pm$ 1.2	69.8 $\pm$ 1.2	69.0 $\pm$ 1.2	70.6 $\pm$ 1.2	68.6 $\pm$ 1.3	0.077
Model 3 (adjusted for multivariate)	73.8 $\pm$ 1.4	70.7 $\pm$ 1.4	68.7 $\pm$ 1.3	70.6 $\pm$ 1.3	66.6 $\pm$ 1.6	0.006
LDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	118.7 $\pm$ 2.5	123.6 $\pm$ 2.5	123.1 $\pm$ 2.5	123.0 $\pm$ 2.5	128.1 $\pm$ 2.5	0.017
Model 3 (adjusted for multivariate)	115.2 $\pm$ 2.9	123.0 $\pm$ 2.7	122.1 $\pm$ 2.6	125.2 $\pm$ 2.7	131.1 $\pm$ 3.3	0.002
Non-HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	132.9 $\pm$ 2.7	138.0 $\pm$ 2.7	137.4 $\pm$ 2.7	137.6 $\pm$ 2.7	144.1 $\pm$ 2.7	0.008
Model 3 (adjusted for multivariate)	129.5 $\pm$ 3.2	137.3 $\pm$ 3.0	136.3 $\pm$ 2.8	140.0 $\pm$ 3.0	146.9 $\pm$ 3.6	0.002

Values are the mean $\pm$ standard error.

*Values are geometric means (95% confidence interval).

Model 2, adjusted for age and body mass index; Model 3, adjusted for age, body mass index, menopause status, smoking, habitual exercise, dietary total energy, SFA, MUFA, n-3 PUFA, n-6 PUFA, dietary cholesterol, and dietary fiber intake.

many confounding factors between nutrition and clinical measures, and that dietary habits over a relatively long period need to be considered when examining the relationship between regular dietary habits and the development of metabolic abnormalities, an observational study of long duration using repeated nutrition surveys may be essential in the future.

The present study suggests that GL is inversely associated with HDL-cholesterol and positively associated with non-HDL-cholesterol in Japanese women. Although GL was also inversely associated with HDL-C in Japanese men, this association might have been affected by alcohol consumption. A diet low in GL might be beneficial in preventing lipid abnormali-

ties and cardiovascular diseases, especially in women.

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References

- Jenkins DJ, Wolever TM, Taylor RH, Barker H, Fielden H, Baldwin JM, Bowling AC, Newman HC, Jenkins AL, Goff DV: Glycemic index of foods: a physiological basis for carbohydrate exchange. *Am J Clin Nutr*, 1981; 34: 362-366
- Foster-Powell K, Holt SH, Brand-Miller JC: International table of glycemic index and glycemic load values: 2002. *Am J Clin Nutr*, 2002; 76: 5-56
- Barclay AW, Petocz P, McMillan-Price J, Flood VM, Prvan T, Mitchell P, Brand-Miller JC: Glycemic index, glycemic load, and chronic disease risk--a meta-analysis of observational studies. *Am J Clin Nutr*, 2008; 87: 627-637
- Frost G, Leeds AA, Dore CJ, Madeiros S, Brading S, Dornhorst A: Glycaemic index as a determinant of serum HDL-cholesterol concentration. *Lancet*, 1999; 353: 1029-1030
- Liu S, Manson JE, Stampfer MJ, Holmes MD, Hu FB, Hankinson SE, Willett WC: Dietary glycemic load assessed by food-frequency questionnaire in relation to plasma high-density-lipoprotein cholesterol and fasting plasma triacylglycerols in postmenopausal women. *Am J Clin Nutr*, 2001; 73: 560-510
- Earl S, Ford ES, Liu S: Glycemic index and serum high-density lipoprotein cholesterol concentration among US adults. *Arch Intern Med*, 2001; 161: 572-576
- Levitan EB, Cook NR, Stampfer MJ, Ridker PM, Rexrode KM, Buring JE, Manson JE, Liu S: Dietary glycemic index, dietary glycemic load, blood lipids, and C-reactive protein. *Metabolism*, 2008; 57: 437-443
- Kim K, Yun SH, Choi BY, Kim MK: Cross-sectional relationship between dietary carbohydrate, glycaemic index, glycaemic load and risk of the metabolic syndrome in a Korean population. *Br J Nutr*, 2008; 100: 576-584
- Murakami K, Sasaki S, Takahashi Y, Okubo H, Hosoi Y, Horiguchi H, Oguma E, Kayama F: Dietary glycemic index and load in relation to metabolic risk factors in Japanese female farmers with traditional dietary habits. *Am J Clin Nutr*, 2006; 83: 1161-1169
- Amano Y, Kawakubo K, Lee JS, Tang AC, Sugiyama M, Mori K: Correlation between dietary glycemic index and cardiovascular disease risk factors among Japanese women. *Eur J Clin Nutr*, 2004; 58:1472-1478
- Vandam RM, Visscher AW, Feskens EJ, Verhoef P, Kromhout D: Dietary glycemic index in relation to metabolic risk factors and incidence of coronary heart disease: the Zutphen Elderly Study. *Eur J Clin Nutr*, 2000; 54: 726-731
- Culbertson A, Kafai MR, Ganji V: Glycemic load is associated with HDL cholesterol but not with the other components and prevalence of metabolic syndrome in the third National Health and Nutrition Examination Survey, 1988-1994. *Int Arch Med*, 2009; 2: 3
- Murakami K, Sasaki S, Takahashi Y, Okubo H, Hirota N, Notsu A, Fukui M, Date C: Reproducibility and relative validity of dietary glycaemic index and load assessed with a self-administered diet-history questionnaire in Japanese adults. *Br J Nutr*, 2008; 99: 639-648
- Friedewald WT, Levy RI, Fredrickson DS: Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem*, 1972; 18: 499-502
- Sasaki S, Yanagibori R, Amano K: Self-administered diet history questionnaire developed for health education: a relative validation of the test-version by comparison with 3-day diet record in women. *J Epidemiol*, 1998; 8: 203-215
- Sasaki S, Ishikawa T, Yanagibori R, Amano K: Responsiveness to a self administered diet history questionnaire in a work-site dietary intervention trial for mildly hypercholesterolemic Japanese subjects: correlation between change in dietary habits and serum cholesterol. *J Cardiol*, 1999; 33: 327-338
- Sasaki S, Ushio F, Amano K, Morihara M, Todoriki T, Uehara Y, Toyooka T: Serum biomarker-based validation of a self-administered diet history questionnaire for Japanese subjects. *J Nutr Sci Vitaminol*, 2000; 46: 285-296
- Okubo H, Sasaki S, Rafamantanantsoa HH, Ishikawa-Takata K, Okazaki K, Tabata I: Validation of self-reported energy intake by a self-administered diet history questionnaire using the doubly labeled water method in 140 Japanese adults. *Eur J Clin Nutr*, 2008; 62: 1343-1350
- Du H, van der A DL, van Bakel MM, van der Kallen CJ, Blaak EE, van Greevenbroek MM, Jansen EH, Nijpels G, Stehouwer CD, Dekker JM, Feskens EJ: Glycemic index and glycemic load in relation to food and nutrient intake and metabolic risk factors in a Dutch population. *Am J Clin Nutr*, 2008; 87: 655-661
- Pischon T, Girman CJ, Sacks FM, Rifai N, Stampfer MJ, Rimm EB: Non-high-density lipoprotein cholesterol and apolipoprotein B in the prediction of coronary heart disease in men. *Circulation*, 2005; 112: 3375-3383
- Shai I, Rimm EB, Hankinson SE, Curhan G, Manson JE, Rifai N, Stampfer MJ, Ma J: Multivariate assessment of lipid parameters as predictors of coronary heart disease among postmenopausal women: potential implications for clinical guidelines. *Circulation*, 2004; 110: 2824-2830
- Shahar E, Chambless LE, Rosamond WD, Boland LL, Ballantyne CM, McGovern PG, Sharrett AR: Plasma lipid

- profile and incident ischemic stroke: the Atherosclerosis Risk in Communities (ARIC) study. *Stroke*, 2003; 34: 623-631
- 23) Ridker P, Rifai N, Cook N, Bradwin G, Buring J: Non-HDL cholesterol, apolipoproteins A-I and B100, standard lipid measures, lipid ratios, and CRP as risk factors for cardiovascular disease in women. *JAMA*, 2005; 294: 326-333
- 24) Oyama T, Saiki A, Endoh K, Ban N, Nagayama D, Ohhira M, Koide N, Miyashita Y, Shirai K: Effect of acarbose, an alpha-glucosidase inhibitor, on serum lipoprotein lipase mass levels and common carotid artery intima-media thickness in type 2 diabetes mellitus treated by sulfonylurea. *J Atheroscler Thromb*, 2008; 15: 154-159

Supplemental Table 1. Characteristics of study participants

	Men (<i>n</i> = 2,257)	Women (<i>n</i> = 1,598)
Age (years)	47.4 ± 6.9	47.0 ± 6.8
Body height (cm)	169.1 ± 6.1	155.9 ± 5.6
Body weight (kg)	66.9 ± 9.4	54.5 ± 8.7
Body mass index (kg/m ²)	23.3 ± 2.9	22.4 ± 3.4
Total cholesterol (mg/dL)	206.1 ± 32.7	209.5 ± 33.4
Triglycerides (mg/dL)*	99.2 (67.0–143.0)	67.1 (48.0–89.0)
HDL cholesterol (mg/dL)	58.6 ± 14.3	68.1 ± 14.6
LDL cholesterol (mg/dL)	124.5 ± 31.0	126.4 ± 31.1
Non-HDL cholesterol (mg/dL)	147.5 ± 34.7	141.5 ± 34.2
Menopause (%)		39.4
Current smoker (%)	53.5	3.4
Alcohol consumption (%)		
Nondrinkers	16.9	59.4
Light drinkers (< 20 g/day)	40.7	38.0
Moderate/heavy drinkers (≥ 20 g/day)	42.4	2.6
Habitual exercise (%)		
No	68.3	79.0
Light	18.7	11.0
Moderate/Strong	12.5	10.0
Energy intake (kcal/day)	2,201 ± 607	1,849 ± 520
Carbohydrate intake (g/day)	315.0 ± 91.6	270.5 ± 72.4
Protein intake (g/day)	65.5 ± 23.4	59.9 ± 20.3
Fat intake (g/day)	53.1 ± 24.5	54.2 ± 23.3
SFA (g/day)	13.5 ± 6.6	14.3 ± 6.7
MUFA (g/day)	19.1 ± 9.5	18.9 ± 8.8
n3PUFA (g/day)	2.6 ± 1.4	2.5 ± 1.3
n6PUFA (g/day)	10.5 ± 4.7	10.5 ± 4.5
Dietary cholesterol (mg/day)	259.8 ± 146.0	242.4 ± 127.8
Fiber intake (g/day)	11.1 ± 4.4	11.8 ± 4.5
Carbohydrate intake (%Energy)	57.8 ± 8.7	59.2 ± 7.0
Fat intake (%Energy)	21.4 ± 6.5	25.8 ± 6.0
Dietary glycemic index	69.3 ± 3.9	68.0 ± 3.7
Dietary glycemic load (/1,000kcal)	88.2 ± 18.3	89.2 ± 14.9

Values are the mean ± standard deviation or %.

*Values are geometric means (interquartile range).

Supplemental Table 2. Contribution (%) of main food groups to dietary glycemic index in Japanese men and women

	Men		Women	
	Mean	SD	Mean	SD
White rice	61.6	± 21.7	53.6	± 20.4
Bread	6.9	± 8.2	8.9	± 8.2
Noodles	5.5	± 5.6	4.5	± 4.5
Confectioneries	5.1	± 4.8	10.1	± 6.9
Sugar	4.9	± 3.5	5.3	± 3.5
Brown rice and other grains	4.4	± 15.7	4.1	± 14.5
Soft drinks	3.6	± 5.6	2.8	± 4.4
Fruits	1.9	± 2.3	3.1	± 2.7
Potatoes	1.4	± 1.3	1.8	± 1.4
Pizza and other grain products	1.2	± 2.5	1.5	± 2.6
Fruit and vegetable juice	1.2	± 2.5	1.2	± 2.3

Values are the mean ± standard deviation.

Supplemental Table 3. Mean lipid levels according to glycemic index quintiles for men and women

	Quintiles of dietary glycemic index					<i>p</i> for trend
	Q1 (lowest)	Q2	Q3	Q4	Q5 (highest)	
Men	<i>n</i> = 456	<i>n</i> = 478	<i>n</i> = 423	<i>n</i> = 453	<i>n</i> = 447	
Glycemic index	≤ 66.10	66.11–68.70	68.71–70.40	70.41–72.60	≥ 72.61	
Total cholesterol (mg/dL)	206.2 ± 1.5	207.6 ± 1.5	206.2 ± 1.6	208.6 ± 1.6	201.8 ± 1.5	0.122
Triglycerides (mg/dL) [†]	99.0 (34.8–281.5)	99.9 (34.9–285.9)	105.8 (37.2–300.9)	97.4 (33.2–285.7)	94.6 (33.1–270.4)	0.200
HDL cholesterol (mg/dL)	58.7 ± 0.7	58.0 ± 0.6	58.5 ± 0.7	58.8 ± 0.7	59.1 ± 0.7	0.484
LDL cholesterol (mg/dL)	124.6 ± 1.4	126.5 ± 1.4	123.2 ± 1.6	127.1 ± 1.5	120.8 ± 1.4	0.131
Non-HDL cholesterol (mg/dL)	147.5 ± 1.6	149.7 ± 1.6	147.6 ± 1.7	149.8 ± 1.7	142.6 ± 1.6	0.080
Women	<i>n</i> = 323	<i>n</i> = 318	<i>n</i> = 332	<i>n</i> = 313	<i>n</i> = 312	
Glycemic index	≤ 65.10	65.11–67.10	67.11–69.00	69.01–71.00	≥ 71.01	
Total cholesterol (mg/dL)	209.5 ± 1.8	208.5 ± 1.8	208.1 ± 1.8	207.4 ± 1.9	214.3 ± 1.9	0.145
Triglycerides (mg/dL) [*]	63.8 (24.9–163.4)	68.4 (26.5–176.7)	65.0 (26.9–156.7)	69.9 (28.1–174.1)	68.9 (27.4–173.2)	0.030
HDL cholesterol (mg/dL)	69.9 ± 0.8	67.0 ± 0.8	68.3 ± 0.8	67.2 ± 0.8	67.9 ± 0.8	0.098
LDL cholesterol (mg/dL)	125.1 ± 1.7	126.0 ± 1.7	125.4 ± 1.7	124.5 ± 1.8	130.9 ± 1.8	0.055
Non-HDL cholesterol (mg/dL)	139.5 ± 1.8	141.6 ± 1.9	139.9 ± 1.8	140.2 ± 2.0	146.4 ± 2.0	0.030

Values are the mean ± standard error.

^{*} Values are geometric means (95% confidence interval).

Supplemental Table 4. Differences in baseline characteristics between nondrinkers and drinkers

	Men						Women				
	Nondrinkers (<i>n</i> =377)			Drinkers (<i>n</i> =1,880)			Nondrinkers (<i>n</i> =949)		Drinkers (<i>n</i> =649)		
	Mean	SD		Mean	SD	<i>p</i> [*]	Mean	SD	Mean	SD	<i>p</i> [*]
Age (years)	47.5	± 6.7		47.4	± 6.9	0.785	47.7	± 6.8	46.0	± 6.6	<0.001
Body mass index (kg/m ²)	23.2	± 3.1		23.3	± 2.8	0.454	22.4	± 3.4	22.4	± 3.4	0.947
Total cholesterol (mg/dL)	208.9	± 30.4		205.5	± 33.1	0.053	210.6	± 32.8	208.0	± 34.3	0.134
Triglycerides (mg/dL) [†]	100.8 (34.2–296.6)			97.6 (34.1–278.9)		0.289	67.4 (26.5–171.4)		64.9 (26.3–159.8)		0.104
HDL cholesterol (mg/dL)	53.3	± 12.4		59.7	± 14.4	<0.001	66.7	± 14.3	70.1	± 14.7	<0.001
LDL cholesterol (mg/dL)	131.9	± 28.6		123.0	± 31.3	<0.001	128.5	± 30.5	123.3	± 31.8	<0.001
Non-HDL cholesterol (mg/dL)	155.6	± 32.1		145.9	± 35.0	<0.001	143.9	± 33.3	137.9	± 35.1	<0.001
Dietary glycemic index	69.2	± 3.6		69.3	± 3.9	0.831	68.2	± 3.7	67.6	± 3.7	0.003
Dietary glycemic load (/1,000kcal)	101.5	± 16.4		85.4	± 17.4	<0.001	92.2	± 14.7	84.6	± 14.1	<0.001
Energy intake (kcal/day)	2,119	± 635		2,217	± 600	0.004	1,818	± 510	1,895	± 532	0.004
Fat intake (%Energy)	22.2	± 6.6		21.1	± 6.5	0.004	25.4	± 5.9	26.2	± 6.1	0.010
Carbohydrate intake (%Energy)	63.8	± 7.7		56.5	± 8.4	<0.001	60.5	± 6.9	57.2	± 6.7	<0.001
Fiber intake (g/day)	11.4	± 4.6		11.0	± 4.4	0.164	11.8	± 4.5	11.8	± 4.6	0.930
SFA (g/day)	13.8	± 6.6		13.5	± 6.5	0.398	13.9	± 6.3	14.9	± 7.1	0.004
MUFA (g/day)	18.8	± 9.5		19.1	± 9.5	0.510	18.2	± 8.3	20.0	± 9.5	<0.001
n3PUFA (g/day)	2.5	± 1.4		2.6	± 1.4	0.067	2.5	± 1.2	2.7	± 1.3	0.005
n6PUFA (g/day)	10.4	± 4.7		10.6	± 4.7	0.648	10.1	± 4.2	11.0	± 4.8	<0.001
Dietary cholesterol (mg/day)	249.4	± 146.2		261.9	± 145.9	0.129	236.4	± 126.1	251.3	± 129.7	0.022

* *t*-test was used to compare the difference between nondrinkers and drinkers.

† Values are geometric means (95% confidence interval).

Supplemental Table 5. Multivariate-adjusted mean lipid levels according to glycemic load quintiles for premenopausal and postmenopausal women

	Quintiles of dietary glycemic load					<i>p</i> for trend
	Q1 (lowest)	Q2	Q3	Q4	Q5 (highest)	
Premenopausal women	<i>n</i> = 220 ≥76.89	<i>n</i> = 220 76.90–84.81	<i>n</i> = 193 84.82–92.03	<i>n</i> = 186 92.04–103.33	<i>n</i> = 150 ≥103.34	
Total cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	198.3 ± 2.0	201.0 ± 2.0	202.1 ± 2.1	202.9 ± 2.2	199.7 ± 2.4	0.431
Model 3 (adjusted for multivariables)	198.2 ± 2.5	201.3 ± 2.2	201.8 ± 2.2	203.1 ± 2.5	199.7 ± 3.4	0.522
Triglycerides (mg/dL)*						
Model 2 (adjusted for age and BMI)	59.6 (56.2–63.1)	61.2 (57.8–64.9)	63.4 (59.6–67.4)	62.2 (58.4–66.3)	64.9 (60.4–69.6)	0.068
Model 3 (adjusted for multivariables)	58.1 (54.1–62.3)	60.3 (56.5–64.2)	62.8 (59.0–66.9)	62.8 (58.6–67.3)	64.3 (58.4–70.7)	0.224
HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	70.0 ± 0.9	70.2 ± 0.9	68.0 ± 1.0	69.2 ± 1.0	66.7 ± 1.1	0.019
Model 3 (adjusted for multivariables)	70.9 ± 1.1	70.8 ± 1.0	68.1 ± 1.0	68.7 ± 1.1	65.0 ± 1.5	0.009
LDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	114.9 ± 1.8	117.0 ± 1.8	119.9 ± 1.9	119.8 ± 2.0	117.9 ± 2.2	0.130
Model 3 (adjusted for multivariables)	114.0 ± 2.3	116.8 ± 2.0	119.4 ± 2.0	120.2 ± 2.2	119.9 ± 3.1	0.100
Non-HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	128.4 ± 1.9	130.8 ± 1.9	134.1 ± 2.1	133.7 ± 2.1	133.0 ± 2.4	0.057
Model 3 (adjusted for multivariables)	127.3 ± 2.4	130.6 ± 2.1	133.6 ± 2.2	134.4 ± 2.4	134.8 ± 3.3	0.063
Postmenopausal women	<i>n</i> = 100 ≤76.89	<i>n</i> = 100 76.90–84.81	<i>n</i> = 126 84.82–92.03	<i>n</i> = 134 92.04–103.33	<i>n</i> = 169 ≥103.34	<i>p</i> for trend
Total cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	221.5 ± 3.3	222.8 ± 3.3	219.1 ± 2.9	226.5 ± 2.8	224.2 ± 2.5	0.323
Model 3 (adjusted for multivariables)	220.6 ± 4.4	223.6 ± 3.8	218.7 ± 3.2	227.5 ± 3.2	223.7 ± 3.6	0.595
Triglycerides (mg/dL)*						
Model 2 (adjusted for age and BMI)	71.1 (65.4–77.3)	71.8 (66.1–78.0)	74.6 (69.3–80.4)	77.3 (71.9–83.0)	81.1 (76.1–86.4)	0.004
Model 3 (adjusted for multivariables)	68.4 (61.3–76.4)	69.2 (62.8–76.2)	72.4 (66.9–78.5)	77.8 (71.8–84.3)	82.8 (75.6–90.7)	0.016
HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	69.5 ± 1.4	69.8 ± 1.4	65.0 ± 1.3	66.9 ± 1.2	64.1 ± 1.1	0.001
Model 3 (adjusted for multivariables)	70.6 ± 1.9	70.9 ± 1.6	65.2 ± 1.4	66.4 ± 1.4	63.1 ± 1.6	0.006
LDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	136.1 ± 3.0	137.4 ± 3.0	137.6 ± 2.7	142.1 ± 2.6	142.3 ± 2.3	0.049
Model 3 (adjusted for multivariables)	134.7 ± 4.0	137.6 ± 3.5	137.2 ± 2.9	143.3 ± 2.9	142.3 ± 3.3	0.180
Non-HDL cholesterol (mg/dL)						
Model 2 (adjusted for age and BMI)	152.0 ± 3.3	153.0 ± 3.2	154.1 ± 2.9	159.5 ± 2.8	160.1 ± 2.5	0.014
Model 3 (adjusted for multivariables)	150.0 ± 4.3	152.7 ± 3.7	153.5 ± 3.1	161.1 ± 3.1	160.6 ± 3.5	0.079

Values are the mean ± standard error.

*Values are geometric means (95% confidence interval).

Model 2, adjusted for age and body mass index; Model 3, adjusted for age, body mass index, smoking, alcohol drinking, habitual exercise, dietary total energy, SFA, MUFA, n-3 PUFA, n-6 PUFA, dietary cholesterol, and dietary fiber intake.