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Dietary glycemic load, glycemic index, and associated factors in a multiethnic cohort of midlife women

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Abstract

Background—Dietary glycemic load (GL) and glycemic index (GI), indicators of the postprandial glucose and insulin response to carbohydrate composition of diet, have been suggested as independent risk factors for cardiovascular disease and diabetes. However, current knowledge about the distribution, correlates, and major contributors of these two measures in human populations is limited.

Objective—To describe the intakes and correlates of GL and GI in African-American, Caucasian, Chinese and Japanese women in the Study of Women's Health Across the Nation (SWAN).

Design—Data are from 2,025 women participating in SWAN, a multi-ethnic, community-based cohort study of women transitioning the menopause. GL and GI were estimated from dietary information obtained at study follow-up visit 05 using a modified Block food frequency questionnaire. The relationship of GL and GI to dietary factors and selected demographic measures, including race/ethnicity, and lifestyle factors was examined using bivariate and multivariate analyses.

Results—GI and GL were consistently lower in Caucasian women than African American, Japanese or Chinese women. Education was inversely associated with GL and alcohol consumption was inversely associated with GI among all the ethnic groups. The association between family income and glycemic measures varied across the ethnic groups. GI was positively associated with consumption of grains and potatoes and inversely associated with consumption of fruits, juices, dairy foods, protein sources and sweets among all the ethnic groups.

Conclusions—It is important for researchers to consider factors such as ethnicity, family income, and alcohol intake as potential confounders when investigating the associations of GL and GI with disease.

INTRODUCTION

There is increasing evidence that postprandial hyperglycemia is an important risk factor for cardiovascular morbidity and mortality in the general population [1]. Consistently, experimental data have suggested that acute hyperglycemia can have adverse effects on the arterial wall through a number of mechanisms, including increased oxidative stress, endothelial dysfunction, and coagulation cascade activation [2]. The concept of a glycemic

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index (GI) was introduced in the 1980s to quantify the postprandial blood glucose and insulin responses to intake of different carbohydrate-containing foods [3]. Subsequently, two measures evolved, the overall dietary GI which represents the quality of carbohydrate intake, and the dietary glycemic load (GL), which represents both the quality and quantity of carbohydrate intake [4]. In several large prospective studies, lower levels of both GL and overall GI were associated with lower risk of cardiovascular disease and diabetes, independent of other factors [5–7]. Diets with lower GI or GL have been beneficial as shown with measures of insulin sensitivity and lipids in recent randomized controlled trials [8,9].

The intakes of GL and overall GI, as well as major food sources of GL, have had limited examination in ethnic groups where there is substantial variation in disease frequencies. Most studies of the GI including the Nurses' Health Study [5,6], Health Professional's Follow-up Study [7], and Atherosclerosis Risk in Communities (ARIC) have characterized Whites or African Americans [10]. In addition, although high GL and GI have been associated with adverse health effects in the majority of epidemiological studies, the debate continues regarding the validity and utility of these two measures [11]. For example, one could argue that the benefits of low-GL diet observed in previous studies could be due to its association with healthy lifestyles and eating habits, which may not have been adequately considered in the data analyses.

The Study of Women's Health Across the Nation (SWAN) provides the opportunity to evaluate GI and GL in a large multi-ethnic cohort. Dietary intake data collected at the fifth year of follow-up were used in the current analysis. This report summarizes and compares the intakes of GL and GI in midlife women of diverse ethnicity, identifies major contributors of GL in this population, and examines the relations of GL and overall GI with selected demographic, lifestyle, and dietary factors.

MATERIALS AND METHODS

Study sample and SWAN dietary questionnaires

SWAN is a multisite, prospective study of menopausal transition among midlife women who were members of the following targeted race/ethnic groups: African American, Caucasian, Chinese, Japanese, and Hispanic [12]. Study participants were recruited through community and population-based sampling at seven clinical sites in the following areas: Boston, MA; Chicago, IL; Detroit area, MI; Los Angeles, CA; Newark, NJ; Oakland, CA; and Pittsburgh, PA. All seven sites enrolled Caucasian women. In addition, Chinese, Japanese, and Hispanic women were enrolled at the Oakland, Los Angeles, and Newark sites, respectively, and African American women were enrolled at the remaining four sites. The 3302 participants were women aged 42 to 52 years at the time of recruitment. The data presented here were collected at the fifth year of SWAN follow-up (visit 05) in 2001–2002. The study was approved by the institutional review board at each site, and written informed consent was obtained from all study participants.

Dietary data

At SWAN visit 05, dietary information was obtained using the SWAN dietary questionnaire, a modification of the 1995 version of the Block food frequency questionnaire (FFQ) [13], covering usual dietary intake during the previous year. The questionnaires were administered by trained interviewers with the use of 3-dimensional models for portion size estimation. Frequency of consumption was reported in one of nine categories ranging from never to every day. The SWAN FFQs were available in English and in versions that provided both English and either Chinese or Japanese. All FFQs included a core food list consisting of 103 food items. This core food list was developed from food items that were identified as the major nutrient contributors in the U.S. diet in the Second National Health and Nutrition Examination Survey (NHANES II). Major U.S. sources of phytoestrogens were also included in the SWAN core food list, including tofu, soy milk, soy sauce, and meat substitutes made from soy. In addition, 12 and 16 ethnic food items were added to the Chinese and Japanese FFQs respectively, to ensure adequate assessment of cultural food practices. The 12 ethnic foods added to the Chinese FFQ were identified based on focus groups, and the 16 ethnic foods added to the Japanese FFQ were identified based on 24-hour recall data in previous studies [14,15]. These additional ethnic foods were also asked of Caucasian respondents at the relevant sites (i.e. Chinese foods at the Oakland site, Japanese foods at the Los Angeles site) to assure that the Caucasian and non-Caucasian questionnaires were comparable within the same site.

The completed FFQs were electronically scanned and nutrient intakes were calculated using the DIETSYS, a program designed for the analysis of the FFQ, by multiplying the frequency of consumption of each food by its nutrient content and the reported portion size, and summing over all foods. The nutrient values were primarily obtained from the USDA nutrient database for standard reference [16], as well as food manufacturers' websites and food labels. Food groups were defined based on the USDA Food Guide Pyramid [17]. For example, the "protein sources" group includes meat, chicken, fish, eggs and nuts. Servings of food groups were calculated by multiplying the frequency of consumption of each food by the reported portion size, summing the grams consumed in each food group, and dividing by the standard serving size as defined in the USDA Food Guide Pyramid [17]. Nutrient estimates from this and earlier versions of the Block questionnaire have been subjected to a number of validation studies and found to be well correlated with reference data [18–20,28,29].

The GI of an individual food, defined as the incremental area under the blood glucose response curve after consumption of 50 grams of carbohydrate from the test food divided by the corresponding area produced by the same amount of carbohydrate from a reference food (usually white bread or glucose) and multiplied by 100, can be determined experimentally using standard methods [3,21]. The GI values (with glucose as the reference) for food items on the SWAN questionnaire were provided by the Department of Nutrition, Clinical Nutrition Research Center, University of North Carolina, which was partially derived from published data sources [22]. The dietary GL of an individual was calculated by multiplying the GI of each food by its non-fiber carbohydrate content, frequency of consumption, and reported portion size, and summing over all foods. Dietary GL thus represents both quality and quantity of carbohydrate intake [4]. Consequently, an individual's overall dietary GI, a variable that represents the overall quality of carbohydrate in the diet [4], was calculated by dividing the dietary GL by the total amount of non-fiber carbohydrate consumed.

Among the 3302 women who originally participated in SWAN, dietary data from visit 05 were not available from the Newark clinical site, eliminating all participants from that site, including the only Hispanic women in SWAN. Of the 2,133 women completing the year 05 follow-up FFQ (618 African Americans, 1056 Caucasians, 216 Chinese and 243 Japanese), dietary data from 107 women were judged as unreliable based on the following criteria: reported total energy intake < 500 kcal/day or > 5,000 kcal/day, skipped > 10 food items listed on the FFQ, or consumption of < 4 or > 17 solid food items per day (56 African Americans, 28 Caucasians, 7 Chinese and 16 Japanese). These data were excluded as were data from a Chinese woman who used the English-language FFQ version, resulting in a total of 2,025 participants with usable dietary data from visit 05.

Other measurements

Standardized questionnaires were used to assess demographic and lifestyle characteristics, including ethnicity and education at the baseline, age, current smoking status, family income, and sports index (i.e., physical activity in sports and exercise, summarized on an ordinal scale ranging from 1–5) at visit 05 [23]. Body mass index (BMI) at visit 05 was computed from measured weight and height (kg/m^2). Regular vitamin or mineral supplement use (at least once a week) and alcohol intake at visit 05 were assessed using the SWAN dietary questionnaire.

Statistical analysis

Characteristics of study participants by race/ethnicity were described by using means and proportions. Dietary GL and overall GI were examined across selected demographic and lifestyle categories as well as quartiles of dietary factors, adjusting for study site. Linear trend tests were performed for ordered categories. Multivariable regression analyses were conducted and included examination of potential effect modification, with statistically significant covariates being included in the statistical models, based on their type III sum of squares. Variables examined included age, ethnicity, education, current smoking status, family income, sports index, BMI, supplement use, alcohol intake, and servings of food groups. Analyses were conducted both with and without adjustment for total energy intake by inclusion of energy in the model. All statistical analyses were performed using SAS software (version 9.1; SAS Institute, Cary, NC).

RESULTS

Of the 2025 women included in this analysis (age range 46–58 yrs), 50.8% were Caucasian, 27.8% were African American, and Chinese and Japanese each constituted 10.3% and 11.2% of the study sample, respectively (Table 1). While the average age was similar across the race/ethnic groups (51 yrs), other characteristics varied by race/ethnicity. African-American women had higher average BMI (33 kg/m^2), whereas Chinese and Japanese women had similar and lower means of BMI (24 kg/m^2). Approximately 20% of African-American women and 10% of Caucasian and Japanese women were current smokers, while almost no Chinese women reported smoking. A greater percentage of Japanese women reported regular supplement use (76%), compared with other groups. On average, African-American women had the highest total energy intake (1811 kcal/d), whereas Chinese women had the lowest total energy intake (1652 kcal/d).

The race/ethnic differences in sources of dietary GL were quite obvious. Table 2 lists the top 20 foods contributing to the dietary GL, by ethnicity and the percent contributed by each food and the cumulative percent. Bread and rice were the top 2 contributors in all groups, providing approximately 10% of total dietary GL among African-American and Caucasian women. Rice was the most important source among Chinese and Japanese women, contributing over 35% of their total GL intake. Orange juice is also a major contributor of dietary GL, ranking third among Chinese and Japanese and fourth among African American and Caucasian women. Foods in the top 10 that were in common for all ethnicities included bread; rice; orange and grapefruit juice; bagels, English muffins, and buns; cookies and cake; and chocolate candy. Among African-American women, regular soft drinks and drinks like Hi-C were major sources, ranking third and sixth in importance. In the other groups, however, these drinks made a considerably smaller contribution to total intake.

As seen in Table 3, both dietary GL and GI were strongly associated with race/ethnicity, with Caucasian women having significantly lower GL than African American women (P = 0.0002) and significantly lower GI than both African American ($P < 0.0001$) and Japanese

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women (*P* = 0.0004). Lower GL and GI were associated with alcohol consumption of more than one drink per day, supplement use, having greater family income, and being in the highest sports index quartile. Current smoking status was significantly associated with dietary GL but was not associated with GI. Body mass index categories were not associated with either GL or GI.

Associations of total energy intake and food groups with GL and GI are summarized in Table 4. Food groups examined were fruits, juices, vegetables, potatoes, dairy foods, grains, protein sources, and sweets, and their component foods are listed in Appendix A. Dietary GL was positively associated with total energy intake and consumption of fruits, juices, potatoes, grains and sweets (after adjustment of energy intake). The correlation of GL with carbohydrate content and energy intake as calories was 0.91 and 0.85, respectively. GI was positively associated with consumption of grains and potatoes and inversely associated with intakes of total energy, fruits, dairy foods, and sweets. The correlation of GI with carbohydrate content and energy intake as calories was −0.11 and −0.08, respectively.

In multiple regression analyses for GL (Table 5), ethnicity-stratified analyses were performed as the associations between a number of factors and GL were modified by ethnic group. Age and sports index were significantly associated with GL only among Caucasian women (*P* = 0.01 and 0.0003, respectively). Higher education level was associated with lower GL among Japanese women, while no significant association was observed among other ethnic groups. Among Chinese and Japanese women, family income was positively associated with GL. Significantly higher GL was observed among Chinese women who smoke compared with non-smokers (*P* = 0.05). Consumption of all the food groups except protein sources were significantly associated with GL among all the ethnic groups, with the intake of grains being the strongest predictor of GL. BMI, alcohol consumption, and supplement use were not associated with GL among all the ethnic groups.

Subgroup analysis by ethnicity was performed in multiple regression analyses for GI as well (Table 6). BMI was significantly associated with GI among Caucasian women only (P = 0.05). Higher alcohol intake was associated with lower GI among Caucasian, African American, and Japanese women. Family income was positively associated with GI among Chinese women only. Intakes of fruit, juice, dairy foods, protein sources and sweets were inversely associated with GI, while consumption of potatoes and grains were positively associated with GI. There are no significant associations between age, smoking status, supplement use, education level, sports index and vegetable intake with GI among all the ethnic groups.

DISCUSSION

Since its development, there has been ongoing controversy about the importance of the GI in characterizing the at-risk environment for diabetes and heart disease. Some of the controversy involves uncertainty regarding whether observed GI/GL associations are a function of type and quantity of carbohydrate or of other factors such as sociodemographics, lifestyle or nutritional contributions of other foods. In this study, we examined selected demographic, lifestyle, and dietary factors for their associations with dietary GL and overall GI in a large population-based multiethnic cohort of women at midlife, hoping to inform this debate.

The different associations of GL and overall GI observed in this study can be attributed to the difference between these two measures. By definition, an individual’s overall GI represents the quality of carbohydrate intake in terms of glycemic response, whereas GL provides a summary measure of both the quality and quantity of carbohydrate in the diet.

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Other work has shown that total carbohydrate content alone could explain 68% of the variance in GL values, and the GI could account for 49% of the variance in GL [26]. In our data, GL is highly correlated with both total carbohydrate intake and energy intake (r = 0.91 and 0.85, respectively) and explains its positive association with all the food groups examined. On the other hand, the associations between overall GI and food groups reflect the overall quality of foods in these food groups. Low GL diets can be achieved in different ways, e.g. low-GI/high-carbohydrate or high-GI/low-carbohydrate (by replacing carbohydrate with fat or protein). Such diets have been associated with a number of different metabolic effects [27]. Consequently, it is argued that both GL and overall GI should be taken into consideration in the research and management of cardiovascular disease and diabetes.

Race/ethnicity

Our data revealed significant ethnic variation in dietary GL and GI, and the magnitude of the observed differences was quite substantial for GL. The average GL of African-American women was approximately 10% greater than that of Caucasian women, and 6% greater than GL of Chinese and Japanese women.

Not surprisingly, there were marked differences in the food sources of GL among different ethnic groups. In particular, among Chinese and Japanese women, rice is the most important source of GL, contributing over 35% of total GL intake, which is far higher than all the other food sources. Among African American and Caucasian women, a more diverse food pattern was seen, with bread, other wheat bread products and rice being the major food sources. The major GL contributors among Caucasian women in this study are similar to findings from the Nurses' Health Study using dietary data collected in 1984 [24]. In that study, cooked potatoes were the most important source of GL, contributing 8% of total GL intake, and this may reflect changes in dietary patterns over time. The degree to which this diversity in food sources as a source of carbohydrate is actually important to glucose response is not well-studied.

Body mass index

No association between BMI and GL was observed in the current study, whereas a significant association was seen for GI among Caucasian women; normal weight subjects were found to have significantly higher GI than overweight and obese subjects in the multivariate analysis. Using waist circumference instead of BMI gave similar results (data not shown). The same association exists among African American and Japanese women as well, although not at a significant level. In addition, findings from NHANES III data also showed an inverse association between BMI and GI [25]. One possible explanation might be that overweight or obese people tend to eat less staple food such as grains and potatoes than normal weight people in order to control weight, most of which have high GI value.

Smoking and alcohol intake

Among NHANES III participants, smoking status was associated with GI but not with GL, and alcohol was not associated with either GL or GI [25]. In the current study, no association was found between smoking and GI and a significant association between smoking and GL was observed among Chinese women. In addition, alcohol intake was inversely associated with GI among all the ethnic groups. A potential explanation for contrasting observations deals with the population. SWAN is limited to women at mid-life while NHANES characterizes both men and women. Furthermore, SWAN includes a much higher proportion of Chinese and Japanese women than does NHANES. The Chinese and Japanese women have different characteristics than the Caucasian and African American women with respect to income, energy intake, and smoking behavior. Thus, the association we observed may be limited to women and a narrow age range.

Education and income

In the present study, both education level and family income were inversely associated with GL and GI in bivariate analyses. Similar findings on the association between education level and GL and GI have also been reported among NHANES III participants [25]. However, in multivariate analysis after adjustment of other factors, education was only inversely associated with GL but not with GI. Furthermore, significant associations of family income with GL and GI were observed among Chinese and Japanese women only. In these two ethnic groups, families with annual income below $20,000 have significantly lower GL and GI levels compared to the other income groups. Therefore, the present study suggested that the association between family income and glycemic measures may vary considerably across ethnic groups. Further exploration of this observation is needed.

Physical activity

The physical activity level of participants was assessed by a self-administered questionnaire [23], and both sports index and total physical activity score were calculated. Sports index was inversely associated with both GL and GI in bivariate analyses, and its association with GL remained significant in multivariate analyses among Caucasian women. Using total physical activity score (sum of active living index, sports index, and household activity index) as the physical activity index had similar results (data not shown). The inverse association between GL and sports index may be an indicator that healthier lifestyles go together (i.e., more recreational activity, more fruit and vegetable consumption).

Dietary factors

As expected, GL is positively associated with servings of most of the food groups examined in the bivariate analyses, including servings of fruits, juices, potatoes, grains, and sweets. In the multivariate analyses, all these associations remained significant. It should be noted that servings of grains was the strongest predictor of GL in the multivariable model, echoing the fact that bread and rice are the two most important contributors of GL in this population. On the other hand, servings of fruits, juices, dairy foods, protein sources, and sweets were all inversely associated with GI in the multivariate analyses, reflecting the fact that most of the foods in these food groups have low or moderate GI values, and consumption of these food groups is associated with lower levels of overall GI. Similar findings on the association of GI with protein intake, fruit and fruit juice servings have also been reported in the Health ABC study [30].

Strengths of this study include the ethnic diversity and the size of the sample. Further, unlike many studies, there are substantial numbers of participants in each of the four race/ethnic groups. These race/ethnic groups generated considerable diversity in terms of nutrient intakes and lifestyle factors. In addition, the inclusion of ethnic food items in the study-specific FFQs allowed an unbiased comparison of GL and overall GI among the different race/ethnic groups.

Our findings come from a study population that is limited to women in a narrow age range, which may preclude generalization to other age groups and men. Other unmeasured confounders may be important but not described. However, it is notable that many of our findings are consistent with findings from NHANES III data [25].

CONCLUSION

In summary, although dietary GL and overall GI have been suggested as independent risk factors for a number of diseases, our knowledge about the distribution, correlates, and major contributors of these two measures in human population is lacking. To our knowledge, this is the only study that examined factors associated with GL and GI in both unadjusted and adjusted analyses, and the only study that investigated the association between ethnicity and intakes of GL and GI. We observed significant associations between GL, GI and a number of demographic and lifestyle factors, including ethnicity, education, income, alcohol intake, and physical activity level. While these findings need to be further verified in larger and more diverse samples, they suggest that it is important for researchers to consider such factors as potential confounders when investigating the associations between GL and GI with disease.

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Table 1

Selected characteristics of study participants, by race/ethnicity

	African American (*n* = 562)	Caucasian (*n* = 1028)	Chinese (*n* = 208)	Japanese (*n* = 227)	*P* value
Age (yrs)	50.9 ± 2.7[1]	51.0 ± 2.7	51.1 ± 2.6	51.2 ± 2.6	0.53
Body mass index (kg/m^2)	32.9 ± 7.8	28.7 ± 6.9	23.8 ± 4.1	24.0 ± 4.2	<0.0001
Current smoker (%)					<0.0001
yes	20.7	10.7	1.0	8.9	
no	79.3	89.3	99.0	91.1	
Alcohol consumption (%)					<0.0001
no alcohol intake	63.7	34.4	74.0	55.5	
< 1 drink/day	31.1	55.2	23.6	33.0	
≥ 1 drink/day	5.2	10.4	2.4	11.5	
Supplement use[2] (%)					<0.0001
yes	61.9	71.4	70.2	76.1	
no	38.1	28.6	29.8	23.9	
Education (%)					<0.0001
< high school	3.8	1.2	10.1	0.9	
= high school	21.5	11.8	16.8	15.0	
> high school	41.0	28.2	21.6	33.0	
college	16.6	23.8	29.3	33.9	
post-college	17.1	35.0	22.1	17.2	
Family income (%)					<0.0001
< $20,000	16.6	3.8	3.6	1.0	
$20,000 – $34,999	17.2	9.2	8.8	6.2	
$35,000 – $49,999	20.7	14.9	11.9	8.5	
$50,000 – $74,999	25.0	22.7	24.9	26.1	
≥ $75,000	20.5	49.4	50.8	58.3	
Sports index	2.6 ± 1.0	3.1 ± 1.1	2.7 ± 1.0	3.0 ± 1.1	<0.0001
Total energy intake (kcal/d)	1811.0 ± 792.8	1772.0 ± 594.1	1652.3 ± 611.3	1705.3 ± 592.9	0.01

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[1]Results are reported as means ± SD.

[2]Regular vitamin or mineral supplement use (at least once a week).

Table 2

Major contributors of dietary glycemic load among study participants, by race/ethnicity[1]

Rank	Description	% of total GL	Cumul. % of GL
	African American		
1	Bread – white, wheat	9.26	9.26
2	Rice	9.03	18.29
3	Regular soft drinks	7.34	25.63
4	Orange juice, grapefruit juice	6.77	32.40
5	Bagels, English muffins, buns	4.18	36.58
6	Drinks like Hi-C	3.80	40.38
7	Cookies, cake	3.78	44.16
8	Chocolate candy	3.65	47.81
9	Sugar	3.54	51.35
10	Salty snacks	3.21	54.56
11	Cornbread, corn tortillas	3.18	57.74
12	White potatoes, not fried	2.99	60.73
13	French fries, fried potatoes	2.96	63.69
14	Apple juice, grape juice	2.83	66.52
15	Bananas	2.61	69.13
16	Cooked cereal or grits	2.41	71.54
17	Biscuits, muffins	2.33	73.87
18	Pancakes, waffles	2.09	75.96
19	Doughnuts, pastry	2.05	78.01
20	Milk	1.97	79.98
	Chinese		
1	Rice	40.2	40.27
2	Bread – white, wheat	6.37	46.64
3	Orange juice, grapefruit juice	4.28	50.92
4	Cookies, cake	3.50	54.42
5	Bananas	3.14	57.56
6	Bagels, English muffins, buns	2.83	60.39
7	Milk	2.65	63.04
8	Dumplings	2.43	65.47
9	Chocolate candy	2.33	67.80
10	Biscuits, muffins	1.95	69.75
11	Cooked cereal or grits	1.64	71.39
12	Salty snacks	1.52	72.91
13	Doughnuts, pastry	1.51	74.42
14	Regular soft drinks	1.50	75.92
15	Noodles	1.49	77.41
16	Apples, applesauce	1.45	78.86
17	Sugar	1.29	80.15

Rank	Description	% of total GL	Cumul. % of GL
18	White potatoes, not fried	1.22	81.37
19	French fries, fried potatoes	1.17	82.54
20	Spaghetti with tomato sauce	1.16	83.70
	Caucasian		
1	Bread – white, wheat	11.62	11.62
2	Rice	8.75	20.37
3	Bagels, English muffins, buns	6.60	26.97
4	Orange juice, grapefruit juice	5.34	32.31
5	Cookies, cake	5.17	37.48
6	Chocolate candy	4.79	42.27
7	White potatoes, not fried	4.30	46.57
8	Milk	3.67	50.24
9	Regular soft drinks	3.59	53.83
10	Salty snacks	3.24	57.07
11	Bananas	3.01	60.08
12	Spaghetti with tomato sauce	2.71	62.79
13	High fiber cereals	2.53	65.32
14	French fries, fried potatoes	2.19	67.51
15	Cornbread, corn tortillas	2.01	69.52
16	Biscuits, muffins	1.99	71.51
17	Dry cereals	1.94	73.45
18	Sugar	1.85	75.30
19	Pizza	1.75	77.05
20	Cooked cereal or grits	1.65	78.70
	Japanese		
1	Rice	35.23	35.23
2	Bread – white, wheat	5.81	41.04
3	Orange juice, grapefruit juice	4.79	45.83
4	Cookies, cake	3.84	49.67
5	Bagels, English muffins, buns	3.75	53.42
6	Chocolate candy	3.01	56.43
7	Salty snacks	2.49	58.92
8	Regular soft drinks	2.46	61.38
9	Doughnuts, pastry	2.41	63.79
10	White potatoes, not fried	2.31	66.10
11	Biscuits, muffins	2.12	68.22
12	Bananas	2.11	70.33
13	Milk	1.96	72.29
14	French fries, fried potatoes	1.89	74.18
15	Cornbread, corn tortillas	1.82	76.00
16	Spaghetti with tomato sauce	1.78	77.78
17	Pancakes, waffles	1.49	79.27

Rank	Description	% of total GL	Cumul. % of GL
18	Dry cereals	1.32	80.59
19	Apple juice, grape juice	1.14	81.73
20	Cooked cereal or grits	1.11	82.84

[1] See Table 3 for mean glycemic load values for each ethnic group.

Table 3

Relations of demographic and lifestyle factors with dietary glycemic load and glycemic index, adjusting for SWAN site

	No.	Dietary glycemic load			Dietary glycemic index		
		Mean[1]	**SE**	***P* value[2]**	**Mean[1]**	**SE**	***P* value[2]**
Ethnicity							
African American	562	106.5	2.1		51.3	0.4	
Caucasian	1028	96.8	1.4		48.8	0.3	
Chinese	208	100.5	4.4		50.5	0.8	
Japanese	227	100.3	4.2	0.002	51.8	0.8	<0.0001
Age groups (yrs)							
46–49	683	104.9	1.7		50.0	0.32	
50–53	923	99.0	1.5		50.1	0.28	
54–58	419	95.8	2.2	0.0005	49.6	0.41	0.49
Body mass index (kg/m^2)							
Normal weight (<25)	725	100.0	1.8		50.5	0.33	
Overweight (25–29.9)	567	97.2	1.9		49.5	0.35	
Obese (≥30)	714	102.6	1.7	0.31	49.8	0.32	0.20
Current smoker							
yes	238	112.2	2.9		50.4	0.55	
no	1724	98.9	1.1	<0.0001	49.9	0.20	0.43
Alcohol consumption							
no alcohol intake	992	102.5	1.4		51.0	0.27	
< 1 drink/day	866	98.8	1.5		49.4	0.28	
≥ 1 drink/day	167	95.5	3.4	0.02	46.6	0.64	<0.0001
Supplement use							
yes	1371	98.2	1.2		49.7	0.22	
no	611	105.7	1.8	0.0006	50.7	0.34	0.009
Education							
< high school	56	115.7	5.9		52.2	1.13	

	No.	Dietary glycemic load			Dietary glycemic index		
		Mean[1]	SE	*P* value[2]	Mean[1]	SE	*P* value[2]
= high school	309	104.7	2.5		50.8	0.48	
> high school	637	97.8	1.8		49.9	0.33	
college	474	97.6	2.0		49.6	0.39	
post-college	540	100.8	1.9	0.11	49.6	0.36	0.01
Family income							
< $20,000	128	113.8	4.0		51.1	0.76	
$20,000 – $34,999	206	108.3	3.1		50.6	0.59	
$35,000 – $49,999	290	103.6	2.6		49.7	0.49	
$50,000 – $74,999	450	101.2	2.1		50.5	0.40	
≥ $75,000	810	96.2	1.6	<0.0001	49.6	0.30	0.06
Sports index							
Q1[3] (low)	434	101.8	2.1		50.6	0.40	
Q2	507	105.6	2.0		50.6	0.37	
Q3	550	99.5	1.9		50.1	0.35	
Q4 (high)	446	95.5	2.1	0.007	48.6	0.40	0.0002

[1] Least-square means were obtained from analysis by using demographic or lifestyle categories as class variables.

[2] For ethnicity, current smoking status and supplement use, the *P* value represents the results from an analysis of covariance. For all the other variables, the *P* value represents the results from a linear trend test.

[3] Q, quartile.

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Table 4

Relations of dietary factors with dietary glycemic load and glycemic index, adjusting for SWAN site[1]

	No.	Dietary glycemic load[2]			Dietary glycemic index		
		Mean[3]	SE	*P* value[4]	Mean[3]	SE	*P* value[4]
Total energy intake							
Q1[5] (low)	506	60.4	1.3		50.6	0.37	
Q2	506	84.5	1.3		50.5	0.37	
Q3	506	105.2	1.3		49.8	0.37	
Q4 (high)	507	151.0	1.3	<0.0001	49.1	0.37	0.002
Servings of fruits							
Q1 (low)	508	98.4	1.0		50.2	0.37	
Q2	503	100.3	1.0		50.7	0.37	
Q3	507	100.5	1.0		50.1	0.37	
Q4 (high)	507	101.9	1.0	0.02	48.9	0.37	0.005
Servings of fruit juices							
Q1 (low)	594	94.2	1.0		49.2	0.35	
Q2	423	99.8	1.1		50.9	0.41	
Q3	467	99.4	1.1		50.3	0.39	
Q4 (high)	541	107.8	1.0	<0.0001	49.8	0.36	0.28
Servings of vegetables							
Q1 (low)	505	101.2	1.0		50.3	0.37	
Q2	507	101.9	1.0		50.1	0.37	
Q3	505	99.5	1.0		50.1	0.37	
Q4 (high)	508	98.5	1.1	0.03	49.4	0.38	0.12
Servings of potatoes							
Q1 (low)	400	96.7	1.2		48.2	0.43	
Q2	619	99.1	0.9		49.3	0.34	
Q3	488	99.9	1.0		50.6	0.38	
Q4 (high)	518	104.7	1.1	<0.0001	51.6	0.37	<0.0001

	No.	Dietary glycemic load[2]			Dietary glycemic index		
		Mean[3]	SE	*P* value[4]	Mean[3]	SE	*P* value[4]
Servings of dairy foods							
Q1 (low)	505	106.0	1.1		52.1	0.37	
Q2	507	102.3	1.0		50.5	0.36	
Q3	507	101.3	1.0		50.0	0.37	
Q4 (high)	506	91.7	1.0	<0.0001	47.4	0.36	<0.0001
Servings of grains							
Q1 (low)	507	84.7	1.0		45.8	0.35	
Q2	505	94.9	0.9		49.3	0.35	
Q3	508	102.6	0.9		51.3	0.35	
Q4 (high)	505	119.6	1.0	<0.0001	53.7	0.35	<0.0001
Servings of protein sources							
Q1 (low)	508	105.6	1.1		49.2	0.37	
Q2	504	103.7	1.0		50.6	0.37	
Q3	503	101.0	1.0		50.8	0.37	
Q4 (high)	510	90.5	1.1	<0.0001	49.4	0.38	0.59
Servings of sweets							
Q1 (low)	380	96.9	1.2		51.2	0.43	
Q2	627	97.6	0.9		50.9	0.33	
Q3	485	100.7	1.0		50.2	0.38	
Q4 (high)	533	105.2	1.1	<0.0001	47.9	0.36	<0.0001

[1]Food groupings are listed in Appendix A.

[2]The analyses for food groups were adjusted for total energy intake.

[3]Least-square means were obtained from analysis by using quartiles of dietary factors as class variables.

[4]The *P* value represents the results from a linear trend test.

[5]Q, quartile.

Table 5

Factors significantly associated with dietary glycemic load in study participants (multivariate model[1])

	Adjusted mean GL for categorical variables and Direction of association with GL for continuous variables[2]			
	Caucasian[3]	**African American[4]**	**Chinese[5]**	**Japanese[6]**
Categorical Variables				
Education				
< high school	102.0	124.4	119.5	**106.2**
= high school	95.6	111.7	127.1	**97.0**
> high school	97.0	107.8	112.7	**90.9**
college	95.8	108.8	114.0	**87.8**
post-college	97.0	108.8	116.9	**81.5**
Family income				
< $20,000	96.7	113.5	**91.3**	**62.5**
$20,000 – $34,999	98.5	114.6	**124.6**	**97.4**
$35,000 – $49,999	98.9	113.4	**120.5**	**96.0**
$50,000 – $74,999	96.8	110.6	**126.7**	**105.1**
≥ $75,000	96.5	109.5	**127.1**	**102.5**
Current smoker				
yes	96.2	113.0	**141.1**	93.6
no	98.7	111.7	**95.0**	91.8
Continuous Variables				
Age	**Inverse[7]**	Inverse	Direct[8]	Direct
Sports index	**Inverse**	Inverse	Direct	Direct
Servings of fruits	**Direct**	**Direct**	**Direct**	Direct
Servings of fruit juices	**Direct**	**Direct**	**Direct**	**Direct**
Servings of vegetables[9]	**Direct**	**Direct**	Direct	**Direct**
Servings of potatoes	**Direct**	**Direct**	**Direct**	**Direct**
Servings of dairy foods	**Direct**	**Direct**	Direct	**Direct**
Servings of grains	**Direct**	**Direct**	**Direct**	**Direct**
Servings of sweets	**Direct**	**Direct**	**Direct**	**Direct**

[1]Adjusted for SWAN site and other variables shown. Analysis was conducted without adjustment for total energy intake. Adjustment for energy produced similar results. No other variables examined contributed to the model at $P < 0.05$ in any of the ethnic groups.

[2]For categorical variables, adjusted mean GL at each level were shown; for continuous variables, the direction of the association with GL was shown. Results in bold represent significant associations with GL in the model ($P < 0.05$).

[3]With no missing data, $n = 980$. Model $R^2 = 81\%$.

[4]With no missing data, $n = 479$. Model $R^2 = 83\%$.

[5]With no missing data, $n = 185$. Model $R^2 = 76\%$.

[6]With no missing data, $n = 210$. Model $R^2 = 83\%$.

[7]Negative association of the continuous variable with GL in the model.

[8]Positive association of the continuous variable with GL in the model.

[9]Not including potatoes.

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Table 6

Factors significantly associated with overall glycemic index in study participants (multivariate model[1])

	Adjusted mean GI for categorical variables and Direction of association with GI for continuous variables[2]			
	Caucasian[3]	**African American[4]**	**Chinese[5]**	**Japanese[6]**
Categorical Variables				
Body mass index (kg/m^2)				
Normal weight (<25)	**49.0**	51.0	47.5	47.4
Overweight (25–29.9)	**47.8**	49.9	47.3	46.7
Obese (≥30)	**48.0**	49.1	49.1	44.8
Alcohol consumption				
no alcohol intake	**50.2**	**52.8**	49.5	**48.9**
< 1 drink/day	**49.0**	**51.5**	48.7	**47.9**
≥1 drink/day	**45.7**	**45.6**	45.7	**42.0**
Family income				
< $20,000	48.7	51.1	**38.2**	35.9
$20,000 – $34,999	48.8	49.3	**50.0**	46.9
$35,000 – $49,999	48.1	49.6	**49.3**	50.8
$50,000 – $74,999	48.1	49.5	**52.3**	48.7
≥$75,000	47.8	50.4	**50.3**	49.1
Continuous Variables				
Servings of fruits	**Inverse[7]**	**Inverse**	Inverse	**Inverse**
Servings of fruit juices	Inverse	**Inverse**	Inverse	Inverse
Servings of potatoes	**Direct[8]**	**Direct**	Direct	Direct
Servings of dairy foods	**Inverse**	**Inverse**	Inverse	**Inverse**
Servings of grains	**Direct**	**Direct**	**Direct**	**Direct**
Servings of protein sources	**Inverse**	**Inverse**	**Inverse**	Inverse
Servings of sweets	**Inverse**	**Inverse**	**Inverse**	**Inverse**

[1]Adjusted for SWAN site and other variables shown. Analysis was conducted without adjustment for total energy intake. Adjustment for energy produced similar results. No other variables examined contributed to the model at $P < 0.05$ in any of the ethnic groups.

[2]For categorical variables, adjusted mean GI at each level were shown; for continuous variables, the direction of the association with GI was shown. Results in bold represent significant associations with GI in the model ($P < 0.05$).

[3]With no missing data, $n = 975$. Model $R^2 = 37\%$.

[4]With no missing data, $n = 489$. Model $R^2 = 37\%$.

[5]With no missing data, $n = 193$. Model $R^2 = 23\%$.

[6]With no missing data, $n = 211$. Model $R^2 = 36\%$.

[7]Negative association of the continuous variable with GI in the model.

[8]Positive association of the continuous variable with GI in the model.

Appendix A

Members of food groups on the SWAN food frequency questionnaire

Fruit group Apples, applesauce Bananas Peaches, apricots, canned or dried Peaches, apricots, fresh Cantaloupe Watermelon Strawberries, other berries Oranges or grapefruit Pickled plums[1] Prunes, or prune juice Mangoes or papayas *Fruit juice group* Orange juice, grapefruit juice Apple juice, grape juice *Vegetable group* String beans, green beans Peas Corn Carrots, or mixed vegetables containing carrots Broccoli Cauliflower or brussels sprouts Spinach, cooked or raw Mustard greens, turnip greens, collards, kale Cole slaw, cabbage Green salad Sweet potatoes, yams Seaweed-Agar[1] Mushrooms[1] Daikon radish, burdock, Kabu[1] Alfalfa sprouts Regular bean sprouts Seaweed (dried and in soup)[1,2] Winter melon, bitter melon[2] Soybean sprouts[2] Preserved vegetables[2] Green leafy vegetables[2] *Potato group* White potatoes, not fried French fries, fried potatoes	*Dairy group* Pizza Cheese dishes without tomato sauce Yogurt, frozen yogurt Whole milk or chocolate whole milk 2% milk or chocolate 2% milk Skim milk, 1% milk Milk in coffee or tea Cream, half & half or nondairy creamer in coffee or tea Chawan Mushi (Egg custard)[1] Ice cream Milk on cereal Cottage cheese Other cheese and cheese spread Instant breakfast milkshakes *Grain group* Bread - white, wheat Corn bread, corn tortillas High fiber cereals Dry cereals Bagels, English muffins, buns Biscuits, muffins Pancakes, waffles Rice Hamburgers, cheeseburgers, beef burrito or tacos Tuna, tuna salad, tuna casserole Spaghetti with tomato sauce Pizza Cheese dishes without tomato sauce Cooked cereals or grits Noodles[1,2] Pasta salad, other pasta without tomato sauce Fried Chinese dumpling[2] Steamed or boiled Chinese dumplings[2]
Protein sources group Beans such as baked beans, kidney beans Dry spiced tofu[1] Hamburgers, cheeseburgers, beef burrito or tacos Beef, including roasts, steaks, or in stir-fry or sandwiches Liver, including chicken livers Pork, including chops, roasts, or in stir-fry Fried chicken Fried fish or fish sandwich Shellfish such as shrimp, crab, oysters, etc. Other fish, broiled or baked Aburage, atsuage[1] Hot dogs Ham, bologna, other lunch meats Peanuts, peanut butter Eggs Fish eaten whole[1] Sausage or bacon Soybeans (fermented or Natto)[1] Soybeans (roasted)[1] Soybeans (fresh green)[1] Tofu, bean curd Koritofu[1] Egg substitutes Fermented bean curd[1,2]	*Sweets group* Sugar or honey in coffee or tea or on cereal Ice cream Doughnuts, pastry Pumpkin pie, sweet potato pie Other pies Chocolate candy, candy bars Regular soft drinks Snapple, Calistoga, sweetened bottled waters or iced teas Cookies or cake

Duck or squab[2] Meat substitutes made from soy Beef stew or pot pie Tuna, tuna salad, tuna casserole Spaghetti with tomato sauce Mixed dishes with beef or pork[1] Miso soup Lentil, pea and bean soups Chicken stew, chicken casserole or stir-fry Bean vermicelli[2] Fried Chinese dumpling[2] Steamed or boiled Chinese dumplings[2]	

[1] On Japanese version of FFQ only.

[2] On Chinese version of FFQ only.

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