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Original article

Dietary glycemic index and glycemic load in relation to general obesity and central adiposity among adults

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SUMMARY

Background & aims: Although the association between dietary Glycemic Index (GI), Glycemic Load (GL) and general/abdominal obesity has extensively been examined, limited data are available in this regard in developing countries. The aim of this study was to examine the association between dietary GI and GL with general and abdominal obesity.
Methods: This cross-sectional study was conducted among adults in Isfahan, Iran. Dietary GI and GL were assessed using a validated dish-based 106-item semi-quantitative food frequency questionnaire (DS-FFQ). Data regarding height, weight and waist circumference were collected using a self-reported questionnaire. Overweight or obesity was defined as body mass index ≥25 kg/m^2, and abdominal obesity was defined as waist circumference ≥80 cm for women and ≥94 cm for men.
Results: There was no significant association between dietary GI and GL and general obesity. After adjustment for potential confounders, participants in the highest quintile of dietary GI had a higher chance for abdominal obesity (OR: 1.29; 95% CI: 1.01–1.64), compared with those in the lowest quintile. No significant association was observed between dietary GL and abdominal obesity. After adjustment for potential confounders, women in the top quintile of dietary GI had higher chance for abdominal obesity compared with those in the bottom quintile (OR: 1.48, 95% CI: 1.02–2.15). No significant association was found between dietary GI and abdominal obesity among men. We failed to find any significant association between dietary GI and general obesity in either gender [Comparing top vs. bottom quintiles, for men: OR: 0.97; 95% CI: 0.74–1.29 and for women: OR: 1.01; 95% CI: 0.75–1.40]. No significant association was found between dietary GL and general [for men: OR: 1.13; 95% CI: 0.85–1.49 and for women: OR: 1.01; 95% CI: 0.76–1.35], as well as abdominal obesity [for men: OR: 1.21; 95% CI: 0.88–1.67 and for women: OR: 1.25; 95% CI: 0.88–1.77].
Conclusions: We found a significant positive association between dietary GI and abdominal obesity. When we conducted analyses stratified by gender, we also observed such association in women, but not in men. No other significant associations were observed between dietary GI and GL with general or abdominal obesity.

A list of abbreviations: GI, Glycemic Index; GL, Glycemic Load; BMI, Body Mass Index; WC, Waist Circumferences; OR, Odds Ratio; CI, Confidence Interval; SEPAHAN, Study on the Epidemiology of Psychological, Alimentary Health and Nutrition project; FGDIs, Functional Gastrointestinal Disorders; DS-FFQ, Dish-based 106-item Semi-quantitative Food Frequency Questionnaire; GPPAQ, General Practice Physical Activity Questionnaire.

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1. Introduction

Obesity is a worldwide public health concern affecting both developed and developing countries [1]. According to national reports, more than 50% of Iranian adults are overweight or obese [2]. Obesity is linked with increased risk of diabetes [3], cardiovascular disease [4], some type of cancers [5–7] and mortality [8].

Among several dietary and non-dietary factors contributing to obesity risk, the quality and quantity of carbohydrate intake is of great importance, in particular in developing countries, where this macronutrient is the main source of energy intake. Previous study among Iranian adults showed that Iranians received more than 60% of their energy intake from carbohydrates, especially refined grains with high Glycemic Index (GI) and Glycemic Load (GL) [9]. Several earlier studies have investigated the association between GI and GL, as indicators of dietary carbohydrate quality, and obesity; however, findings are inconsistent. A cross-sectional study on Spanish adults revealed that dietary GL was negatively associated with body mass index (BMI), but they found no significant association between dietary GI and BMI [10]. Another cross-sectional study on Japanese women showed that dietary GI and GL were positively associated with BMI [11]. These associations were also reported in children and adolescents [12]. Findings from cohort studies were also controversial. Among adult Danes, high-GL diets, not high GI diets, were associated with increased body weight, body fat mass and waist circumference (WC) in women but not in men [13]. Another population-based prospective cohort study reported that GI was not linked with body weight changes but positively linked with changes in WC. Such findings were not found between dietary GL and body weight and WC [14].

Most previous studies on dietary GI and GL in relation to obesity have been conducted in developed countries and there is limited information in this regard in developing countries including the Middle East. Assessing the relationship between indicators of carbohydrate quantity and quality is particularly relevant for the Middle Eastern population, where more than 60% of total energy intake is taken from carbohydrates, mostly from refined grains. In addition, pattern of obesity in these countries seems to be different from that in other nations. Therefore, this study was conducted to determine the association between dietary GI and GL and overweight/obesity.

2. Methods and subjects

2.1. Study design and population

This cross-sectional study was done within the framework of the Study on the Epidemiology of Psychological, Alimentary Health and Nutrition (SEPAHAN) project, which is a cross-sectional study that investigates the prevalence of functional gastrointestinal disorders (FGIDs) and their relationship with lifestyle factors and psychological disorders. Details about SEPAHAN project have been published previously [15]. This study was performed among Iranian general adults working in 50 different healthcare centers affiliated to Isfahan University of Medical Sciences (IUMS) across Isfahan province. To calculate required sample size, we hypothesized the prevalence of FGDIs as 15%. Considering the study power of 80% and type 1 error of 5%, the minimum required sample size for the current analysis was 1387 subjects based on suggested formula for cross-sectional studies. To collect information about anthropometric measures, demographic and lifestyle factors, including dietary intakes and physical activity, self-administered questionnaires distributed among 10,087 subjects aged 18–55 years, and 8691 participants returned the completed questionnaires (response rate: 86.16%). In the current study, we excluded subjects who reported their total daily energy intake outside the range of 800–4200 kcal/d. These exclusions left 6724 and 5219 participants with complete data for analysis on general and abdominal obesity, respectively. All participants provided written inform consent forms. The study protocol was approved by the Regional Bioethics Committee of Isfahan University of Medical Sciences.

2.2. Dietary intakes assessment

Dietary intakes of participants were assessed using a Willett-format dish-based 106-item semi-quantitative food frequency questionnaire (DS-FFQ), which was designed and validated specifically for Iranian adults. Detailed information regarding the design, food items, as well as validity and reliability of this questionnaire has been published elsewhere [16]. Briefly, the questionnaire included five categories: 1) mixed dishes (cooked or canned; 29 items); 2) all grain-based foods (different types of bread, cakes, biscuits and potato, 10 items); 3) dairy products (dairy products, butter and cream, 9 items); 4) fruits and vegetables (22 items); and 5) miscellaneous food items and beverages (including sweets, fast foods, nuts, desserts and beverages, 36 items). To develop the questionnaire, a comprehensive list of foods and dishes commonly consumed by Iranian adults was constructed. Then, we chose those foods that were nutrient-rich, consumed reasonably often, or contributed largely to between person variations. To construct a list of commonly consumed foods, four nutrition experts held several sessions to discuss the mainly consumed foods. The basis for choosing a food as a common food item was dietary records and recalls that had been taken in our previous studies. Food items that were consumed at least once a week were considered as foods reasonably often. This process led to the remaining of the 106 food items in the questionnaire. For each food item, a commonly consumed portion size was defined. Participants were asked to report their dietary intakes of foods and mixed dishes based on nine multiple choice frequency response categories varying from “never or less than once a month” to “12 or more times per day”. The frequency response categories for the food list varied from six to nine choices. For foods consumed infrequently, we omitted the high-frequency categories, while for common foods with a high consumption, the number of multiple choice categories increased. For instance, the frequency response for tuna consumption included 6 categories, as follows: never or less than once/month, 1–3 times/month, 1 time/week, 2–4 times/week, 5–6 times/week and 1–2 times/day, and for tea consumption, the frequency response included 9 categories, as follows: never or less than 1 cup/month, 1–3 cups/month, 1–3 cups/week, 4–6 cups/week, 1 cup/day, 2–4 cups/day, 5–7 cups/day, 8–11 cups/day and ≥12 cups/day. Finally, we computed daily intakes of all food items and then converted them to grams per day using household measures. Daily nutrient intakes of each participant were estimated based on the US Department of Agriculture food-composition database.

The correlation coefficient between carbohydrates intake derived from the DS-FFQ vs. the average of 3-d dietary records was 0.81, which indicated that the DS-FFQ provides a reasonable measure of total carbohydrate intake over a long period.

2.3. Assessment of dietary GI and GL

Total dietary GI was calculated using the following formula: $\sum(GI_a \times \text{available carbohydrate}_a)$/total available carbohydrate, where available carbohydrate was calculated as total carbohydrate$_a$ minus fiber$_a$ [17]. The total carbohydrate and fiber content of foods were derived from the US Department of Agriculture food-composition table. Of the 85 carbohydrate containing foods in our food list, GI values for only 6 foods could be derived from the Iranian GI table [18], because the table does not cover the GI of all available foods. Therefore, GI values for 62 other foods were derived from the International tables [19,20]. For the remaining 17 foods, GI values were not available in these tables; thus, they were estimated based on physically and chemically similar foods [21]. For example, the GIs of some traditional sweets and desserts, such as Gaz, which is mainly made of sugar and nuts (almond or pistachios), were considered to be the same as sugar, and that of Gooshfil, which mainly consists of white flour and sugar, was considered to be the same as English muffin bread. The GI values of rice and dates were estimated as the mean values of different brands. All derived GI values were relative to glucose as the reference food. The GIs of composite mixed meals were estimated based on the GIs of individual food components [17]. The dietary GL was calculated as (total GI $\times$ total available carbohydrate)/100 [17] and expressed as g/d. We used the energy-adjusted amount of total carbohydrate intake computed through the residual method, as suggested by Willett and Stampfer [22].

2.4. Anthropometric assessment

Data regarding height, weight and WC were collected using a self-reported questionnaire. BMI was calculated as weight (in kilograms) divided by the height (in meters squared). Participants were classified into two categories based on their BMI: normal weight ($\leq$24.9 kg/m^2) and overweight or obese ($\geq$25 kg/m^2). Abdominal obesity was defined based on WC. Abdominal obesity was identified based on criteria proposed by Lean et al. [23]. Participants were categorized into two groups based on their WC: normal (<80 cm for women and <94 cm for men) and abdominally obese ($\geq$80 cm for women and $\geq$94 cm for men).

The validity of self-reported weight, height and WC was examined in a pilot study on 200 participants from the same population. In the validation study, self-reported values of anthropometric indices were compared with measured values. The correlation coefficients between self-reported weight, height and WC and the corresponding measured values were 0.95 ($P < 0.001$), 0.83 ($P < 0.001$) and 0.60 ($P < 0.001$), respectively. The correlation coefficient for computed BMI from self-reported values and the one from measured values was 0.70 ($P < 0.001$). These data indicated that the self-reported values of anthropometric measures provide a reasonable measure for these indices.

2.5. Assessment of other variables

Information about age, gender, marital status (married, single, divorced and widowed), education (university graduate and below that), family size ($\leq$4/>4 members), smoking status (non-smoker, former smokers and current smokers), breakfast skipping (skippers/non-skippers), home ownership (owner/non-owner), diabetes (yes/no), hyperlipidemia (yes/no), and hypertension (yes/no) were collected using a pretested self-administered questionnaire. Those who were consuming breakfast <4 times/week were defined as breakfast skippers. Physical activity levels of participants were assessed using the General Practice Physical Activity Questionnaire (GPPAQ) [24]. This questionnaire is a simple, four-level physical activity index (PAI) reflecting an individual's current physical activity. Participants were classified into four categories: active (>3 h/week), moderately active (1–3 h/week), moderately inactive (<1 h/week), and inactive (no physical activity). In the current analysis, we classified participants into two categories: <1 h/week (physically inactive) or $\geq$1 h/week (physically active).

2.6. Statistical analysis

Energy-adjusted dietary GI and GL were used to categorize participants into quintiles. General characteristics across quintiles of dietary GI and GL were expressed as means ±SDs for continuous variables and percentages for categorical variables. To examine the differences across quintiles, we used ANOVA for continuous variables and a chi-square test for categorical variables.

Dietary intakes of study participants across quintiles of dietary GI and GL were compared using one-way ANOVA. The multivariable-adjusted means of weight, BMI and waist circumferences across quintiles of dietary GI and GL were compared using ANCOVA. We also used binary logistic regressions to estimate ORs and 95% CIs for the presence of general and abdominal obesity across quintiles of dietary GI and GL in crude and multivariable-adjusted models. In these analyses, age, sex and total energy intake were controlled for in the first model. Further adjustment was made for marital status (married, single, divorced and widowed), educational levels (university graduate and below that), family size ($\leq$4/>4 members), smoking (non-smoker, former smokers and current smokers), physical activity (<1 h/week/$\geq$1 h/week), breakfast skipping (skippers/non-skippers), and home ownership (owner/non-owner) in the second model. P for trends was determined by considering quintiles of dietary GI and GL as ordinal variables in the logistic regression analysis. All statistical analyses were done using the Statistical Package for Social Sciences (version 20; SPSS Inc.). $P < 0.05$ was considered statistically significant.

3. Results

General characteristics of study participants are presented in Table 1. Compared with those in the first quintile, participants in top quintile of dietary GI were younger, less likely to be females, current smokers, physically active and to have diabetes. Within the GL quintiles, participants in the fifth quintile were less likely to be married, current smoker, physically active and to have diabetes and more likely to be breakfast skipper and home ownership compared with those in the first quintile.

Comparing dietary intakes across GI quintiles, we found that participants in the top quintile had lower intakes of fruits, vegetables, white, red and organ meats, legumes, nuts, sweets, oils, total energy, carbohydrate, protein, fat, dietary fiber, vitamin B6 and magnesium and higher intakes of dairy products, grains, sweets and vitamin B12 compared with those in the bottom quintile. Participants in the highest quintile of dietary GL had lower intakes of vegetables, white, red and organ meats, legumes, nuts, total energy, protein, fat, dietary fiber, vitamin B6, vitamin B12 and magnesium and higher intakes of fruits, dairy products, grains, carbohydrates and folate compared with those in the lowest quintile (Data not shown).

Crude and multivariable-adjusted means of anthropometric indicators across quintiles of dietary GI and GL are shown in Table 2. Neither in crude nor in adjusted models, we found a significant difference in anthropometric indicators comparing quintiles of dietary GL. After adjustment for age and energy intake, women in the top quintile of dietary GI tended to have higher WC than those in the bottom quintile (86.0 ± 0.1 vs. 82.5 ± 0.1 cm; $P = 0.05$). This was also the case when we took other potential confounders into account (86.6 ± 1.2 vs. 82.3 ± 1.3 cm; $P = 0.07$).

Crude and multivariable-adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for general and abdominal obesity across quintiles of dietary GI and GL are provided in Table 3. There was no significant association between dietary GI and GL and general

Table 1
General characteristics of study participants across quintiles of glycemic index and glycemic load.[a]

Variables	Glycemic index			P-value[b]	Glycemic load			P-value[b]
	Q_1	Q_3	Q_5		Q_1	Q_3	Q_5	
Subjects, n	1344	1345	1344		1344	1345	1344	
Mean ± SD	69.2 ± 7.3	78.41 ± 7.3	107.3 ± 20.6		215 ± 43.2	317.9 ± 8.8	457.5 ± 107.4	
Median	68.6	77.49	103.76		229.1	318	423.9	
Lower limit	44.73	64.63	78.48		1.89	302.3	372.8	
Upper limit	87.14	97.36	351.20		262.4	333	1700.9	
Age (y)	37.5 ± 8	36.2 ± 8.1	36.9 ± 8.1	<0.001	36.7 ± 8.2	36.9 ± 8.0	37 ± 7.9	0.20
Gender (female) (%)	40	37.2	40	0.67	43.7	35.4	42.6	<0.001
Married (%)	82	81.3	83.4	0.40	81.5	83.4	83.9	0.61
University graduated (%)	58.8	62.2	61.2	0.34	58.3	58.1	62.5	0.09
Family size (>4 people) (%)	11.4	10.5	9.3	0.39	11	9.4	10.1	0.77
Current smoker (%)	5.2	3.5	3.7	0.04	5.8	4.1	3.4	0.005
Physically active (≥1 h/week) (%)	37.8	31	33.5	0.001	37.2	35.1	30.9	0.005
Breakfast skipping (≥4 times/week) (%)	77.6	75.2	78	0.22	75.8	75.2	80.3	0.01
Home ownership (non-owner) (%)	33.4	32.8	29	0.13	32	28.8	32.1	0.05
Diabetes (%)	3.1	1.6	1.8	0.03	2.3	2.3	1.6	0.01
Hyperlipidemia (%)	8.7	8.5	9.0	0.79	8.3	8.5	9.3	0.67
Hypertension (%)	3.7	4.5	3.9	0.48	3.8	3.6	3.6	0.47

[a] Data are mean ± standard deviation (SD).
[b] Obtained from ANOVA or chi-square test, where appropriate.

obesity. After adjustment for potential confounders, participants in the highest quintile of dietary GI had a higher chance of abdominal obesity (OR: 1.29; 95% CI: 1.01–1.64), compared with those in the lowest quintile. There was a significant association between dietary GL and abdominal obesity (OR: 1.28; 95% CI: 1.07–1.54); however, after adjustment for potential confounders, the association became non-significant (OR: 1.24; 95% CI: 0.98–1.56).

Gender-stratified crude and multivariable-adjusted ORs and 95% CIs for general and abdominal obesity across quintiles of dietary GI and GL are provided in Table 4. No significant association was observed between dietary GI and GL and general obesity in men. With regards to abdominal obesity, men in the top quintile of dietary GI and also GL had a higher chance for abdominal obesity compared with those in the bottom quintile [Comparing top vs.

Table 2
Gender-stratified crude and multivariable-adjusted means for anthropometric measures across quintiles of glycemic index and glycemic load.[a]

Variables	Glycemic index			P-value[b]	Glycemic load			P-value[b]
	Q_1	Q_3	Q_5		Q_1	Q_3	Q_5	
Men								
Subjects, n	537	500	537		587	476	573	
Weight								
Crude	63.8 ± 0.37	63 ± 0.36	63.3 ± 0.37	0.22	63.5 ± 0.39	63.1 ± 0.36	63.2 ± 0.38	0.84
Model I[c]	64.0 ± 0.38	62.9 ± 0.37	63.4 ± 0.37	0.11	63.8 ± 0.41	62.9 ± 0.37	63.4 ± 0.38	0.54
Model II[d]	64.05 ± 0.49	62.7 ± 0.45	63.1 ± 0.47	0.17	63.3 ± 0.50	62.6 ± 0.46	63.02 ± 0.48	0.87
BMI								
Crude	24.7 ± 0.14	24.5 ± 0.14	24.5 ± 0.14	0.15	24.7 ± 0.15	24.5 ± 0.14	24.5 ± 0.15	0.58
Model I	24.8 ± 0.14	24.4 ± 0.14	24.5 ± 0.14	0.09	24.9 ± 0.16	24.4 ± 0.14	24.6 ± 0.15	0.20
Model II	24.7 ± 0.18	24.4 ± 0.17	24.4 ± 0.18	0.56	24.6 ± 0.19	24.2 ± 0.17	24.4 ± 0.18	0.38
Subjects, n	405	395	400		458	354	421	
WC								
Crude	82.9 ± 0.51	83.3 ± 0.50	83.6 ± 0.50	0.45	82.8 ± 0.53	84.3 ± 0.49	83.7 ± 0.51	0.32
Model I	83.04 ± 0.52	83.2 ± 0.51	83.7 ± 0.51	0.61	83.1 ± 0.56	84.1 ± 0.50	83.8 ± 0.52	0.56
Model II	82.7 ± 0.66	83.3 ± 0.60	83.7 ± 0.63	0.82	82.7 ± 0.69	84.1 ± 0.60	83.6 ± 0.64	0.49
Women								
Subjects, n	772	819	785		723	835	750	
Weight								
Crude	76.1 ± 0.50	76 ± 0.52	76.4 ± 0.50	0.88	76.4 ± 0.48	75.5 ± 0.53	76.03 ± 0.48	0.79
Model I	76.1 ± 0.51	76 ± 0.52	76.4 ± 0.50	0.89	76.4 ± 0.49	75.5 ± 0.54	76.06 ± 0.49	0.79
Model II	76.2 ± 0.65	75.9 ± 0.63	76.5 ± 0.59	0.87	76.9 ± 0.61	75.5 ± 0.66	76.3 ± 0.58	0.47
BMI								
Crude	25.5 ± 0.15	25.4 ± 0.16	25.6 ± 0.15	0.20	25.5 ± 0.14	25.4 ± 0.16	25.5 ± 0.15	0.93
Model I	25.6 ± 0.15	25.4 ± 0.16	25.7 ± 0.15	0.11	25.6 ± 0.15	25.3 ± 0.16	25.5 ± 0.15	0.64
Model II	25.6 ± 0.19	25.2 ± 0.19	25.6 ± 0.18	0.31	25.7 ± 0.18	25.3 ± 0.19	25.4 ± 0.17	0.40
Subjects, n	613	633	626		563	669	604	
WC								
Crude	82.6 ± 0.1	85.4 ± 0.1	86 ± 0.1	0.06	82.5 ± 0.93	83.9 ± 1.05	85.2 ± 0.97	0.18
Model I	82.5 ± 1.0	85.5 ± 1.0	86 ± 0.1	0.05	82.2 ± 0.97	84.2 ± 1.1	84.9 ± 0.98	0.13
Model II	82.3 ± 1.3	84 ± 1.2	86.6 ± 1.2	0.07	81.2 ± 1.2	83.7 ± 1.3	84.4 ± 1.2	0.16

[a] Data are mean ± standard error (SE).
[b] Obtained from ANCOVA.
[c] Model I: adjusted for age and energy intake.
[d] Model II: additionally, adjusted for marital status, education, family size, smoking status, physical activity, breakfast skipping and home ownership.

Table 3
Crude and multivariable-adjusted ORs (95% CI) for general and abdominal obesity across quintiles of glycemic index and glycemic load.[a]

Variables	Glycemic index			P-trend[b]	Glycemic load			P-trend[b]
	Q_1	Q_3	Q_5		Q_1	Q_3	Q_5	
	<71.8	77.8–83.2	>90.9		<176.9	216.8–247.5	>287.2	
Subjects, n	1344	1345	1344		1344	1345	1344	
General obesity								
Crude	1.00	0.92 (0.79–1.07)	1.04 (0.89–1.21)	0.85	1.00	0.93 (0.80–1.08)	1.09 (0.94–1.27)	0.29
Model I[c]	1.00	0.88 (0.75–1.03)	1.03 (0.88–1.20)	0.90	1.00	0.88 (0.75–1.04)	1.08 (0.93–1.26)	0.30
Model II[d]	1.00	0.83 (0.67–1.02)	1.03 (0.84–1.26)	0.43	1.00	0.87 (0.70–1.08)	1.09 (0.89–1.33)	0.32
	<71.9	77.9–83.4	>91.1		<178.9	219.3–250.9	>290.7	
Subjects, n	1043	1044	1043		1043	1044	1043	
Abdominal obesity								
Crude	1.00	1.18 (0.99–1.40)	1.33 (1.12–1.59)	0.006	1.00	1.39 (1.17–1.66)	1.34 (1.12–1.59)	<0.001
Model I	1.00	1.10 (0.91–1.32)	1.32 (1.10–1.59)	0.01	1.00	1.15 (0.94–1.39)	1.28 (1.07–1.54)	0.004
Model II	1.00	0.98 (0.77–1.25)	1.29 (1.01–1.64)	0.07	1.00	1.17 (0.91–1.50)	1.24 (0.98–1.56)	0.03

[a] Data are OR (95% CI).
[b] Obtained from logistic regression.
[c] Model I: adjusted for age, sex and energy intake.
[d] Model II: additionally, adjusted for marital status, education, family size, smoking status, physical activity, breakfast skipping and home ownership.

bottom quintiles of dietary GI: OR: 1.33; 95% CI: 1.05–1.68 and for dietary GL: OR: 1.41; 95% CI: 1.11–1.79]; however, the association became non-significant in the fully adjusted model [For dietary GI: OR: 1.18; 95% CI: 0.86–1.62 and for dietary GL: OR: 1.21; 95% CI: 0.88–1.67]. Although no significant association was observed between dietary GI and general obesity in women, it was positively associated with abdominal obesity after controlling for potential confounders (Comparing top vs. bottom quintiles: OR: 1.48, 95% CI: 1.02–2.15). No significant association was found between dietary GL and general as well as abdominal obesity in women.

We repeated the above-mentioned analyses by excluding diabetic patients (Table 5). Again, no significant association between dietary GI and GL and general obesity was observed. After adjustment for age, sex and energy intake, we found a significant positive association between dietary GI and GL and abdominal obesity [For dietary GI: OR: 1.34; 95% CI: 1.11–1.61 and for dietary GL: OR: 1.30; 95% CI: 1.08–1.56]; however, after adjustment for further potential confounders, the association became non-significant [For dietary GI: OR: 1.27; 95% CI: 0.99–1.61 and for dietary GL: OR: 1.24; 95% CI: 0.98–1.57].

Gender-stratified analyses were also done again by excluding diabetic patients. No significant association was observed between dietary GI and GL and general obesity in men. In terms of abdominal obesity, men in the top quintile of dietary GI and also GL had a higher chance for abdominal obesity compared with those in the bottom quintile [Comparing top vs. bottom quintiles of dietary GI: OR: 1.35; 95% CI: 1.07–1.71 and for dietary GL: OR: 1.42; 95% CI: 1.11–1.81]; however, these associations became non-significant in fully adjusted model [For dietary GI: OR: 1.17; 95% CI: 0.85–1.62 and for dietary GL: OR: 1.20; 95% CI: 0.87–1.66]. No significant association was observed between dietary GI and GL and general obesity in women. Although a significant positive association between

Table 4
Gender-stratified crude and multivariable-adjusted ORs (95% CI) for general and abdominal obesity across quintiles of glycemic index and glycemic load.[a]

Variables	Glycemic index			P-trend[b]	Glycemic load			P-trend[b]
	Q_1	Q_3	Q_5		Q_1	Q_3	Q_5	
Men								
Subjects, n	537	500	537		587	476	573	
General obesity								
Crude	1.00	0.95 (0.77–1.16)	1.02 (0.84–1.25)	0.83	1.00	1.02 (0.84–1.26)	1.08 (0.88–1.33)	0.44
Model I[c]	1.00	0.89 (0.73–1.10)	1.01 (0.82–1.23)	0.73	1.00	0.92 (0.74–1.15)	1.05 (0.85–1.29)	0.53
Model II[d]	1.00	0.85 (0.64–1.12)	0.97 (0.74–1.29)	0.83	1.00	0.97 (0.72–1.30)	1.13 (0.85–1.49)	0.26
Subjects, n	405	395	400		458	354	421	
Abdominal obesity								
Crude	1.00	1.07 (0.85–1.34)	1.36 (1.08–1.71)	0.03	1.00	1.35 (1.06–1.69)	1.46 (1.15–1.85)	0.001
Model I	1.00	0.97 (0.77–1.23)	1.33 (1.05–1.68)	0.04	1.00	1.17 (0.91–1.51)	1.41 (1.11–1.79)	0.006
Model II	1.00	0.85 (0.62–1.16)	1.18 (0.86–1.62)	0.41	1.00	1.12 (0.80–1.56)	1.21 (0.88–1.67)	0.16
Women								
Subjects, n	772	819	785		723	835	750	
General obesity								
Crude	1.00	0.94 (0.73–1.20)	1.07 (0.84–1.36)	0.57	1.00	0.91 (0.71–1.16)	1.17 (0.93–1.47)	0.31
Model I	1.00	0.90 (0.70–1.16)	1.05 (0.83–1.35)	0.63	1.00	0.84 (0.65–1.08)	1.16 (0.92–1.46)	0.33
Model II	1.00	0.76 (0.56–1.05)	1.01 (0.75–1.40)	0.39	1.00	0.69 (0.51–0.96)	1.01 (0.76–1.35)	0.96
Subjects, n	613	633	626		563	669	604	
Abdominal obesity								
Crude	1.00	1.38 (1.03–1.84)	1.35 (1.01–1.8)	0.1	1.00	1.17 (0.88–1.56)	1.14 (0.87–1.50)	0.17
Model I	1.00	1.33 (0.99–1.79)	1.33 (0.99–1.78)	0.13	1.00	1.11 (0.81–1.50)	1.13 (0.86–1.49)	0.22
Model II	1.00	1.23 (0.84–1.79)	1.48 (1.02–2.15)	0.07	1.00	1.16 (0.79–1.71)	1.25 (0.88–1.77)	0.14

[a] Data are OR (95% CI).
[b] Obtained from logistic regression.
[c] Model I: adjusted for age and energy intake.
[d] Model II: additionally, adjusted for marital status, education, family size, smoking status, physical activity, breakfast skipping and home ownership.

Table 5
Crude and multivariable-adjusted ORs (95% CI) for general and abdominal obesity across quintiles of glycemic index and glycemic load after excluding diabetic patients.[a]

Variables	Glycemic index			P-trend[b]	Glycemic load			P-trend[b]
	Q_1	Q_3	Q_5		Q_1	Q_3	Q_5	
	<71.9	77.8–83.2	>91.01		<177	217.1–248	>287.4	
Subjects, n	1302	1324	1320		1313	1314	1323	
General obesity								
Crude	1.00	0.93 (0.80–1.09)	1.06 (0.91–1.24)	0.56	1.00	0.93 (0.80–1.09)	1.09 (0.94–1.27)	0.24
Model I[c]	1.00	0.90 (0.77–1.06)	1.05 (0.90–1.23)	0.62	1.00	0.89 (0.75–1.05)	1.08 (0.93–1.27)	0.25
Model II[d]	1.00	0.83 (0.67–1.02)	1.03 (0.84–1.27)	0.35	1.00	0.87 (0.70–1.08)	1.08 (0.89–1.32)	0.32
	<71.9	77.9–83.5	>91.1		<179	219.5–251.4	>291.2	
Subjects, n	1014	1026	1023		1019	1023	1027	
Abdominal obesity								
Crude	1.00	1.18 (0.99–1.41)	1.35 (1.13–1.61)	0.004	1.00	1.42 (1.19–1.70)	1.35 (1.13–1.61)	<0.001
Model I	1.00	1.10 (0.91–1.33)	1.34 (1.11–1.61)	0.009	1.00	1.18 (0.97–1.43)	1.30 (1.08–1.56)	0.002
Model II	1.00	0.96 (0.75–1.22)	1.27 (0.99–1.61)	0.10	1.00	1.21 (0.94–1.56)	1.24 (0.98–1.57)	0.03

[a] Data are OR (95% CI).
[b] Obtained from logistic regression.
[c] Model I: adjusted for age, sex and energy intake.
[d] Model II: additionally, adjusted for marital status, education, family size, smoking status, physical activity, breakfast skipping and home ownership.

dietary GI and abdominal obesity was observed in crude model in women (OR: 1.35; 95% CI: 1.00–1.82), this association disappeared after taking potential confounders into account (OR: 1.43; 95% CI: 0.98–2.08). No significant association was found between dietary GL and abdominal obesity in women (Data not shown).

4. Discussion

We found that a high dietary GI, compared to a low dietary GI, was associated with greater odds of abdominal obesity in women, but not in men. We failed to find any significant association between dietary GI and general obesity in either gender. In addition, no significant association was observed between dietary GL and general as well as abdominal obesity in either gender.

The prevalence of overweight and obesity is increasing in the world [25]; therefore, finding modifiable risk factors of obesity, including dietary GI and GL, is of high priority. We observed a positive association between dietary GI and abdominal obesity in women, but not in men. Our results were in line with a large prospective cohort study in five European countries that showed a significant positive association between dietary GI and waist circumference [14]. A systematic review and meta-analysis showed that long-term consumption of low-GI diets might be useful for prevention of obesity and obesity-related diseases [26]. In contrast to our findings, some studies have failed to find such associations. A pooled analysis showed no significant association between dietary GI and chance of being obese [27]. Different findings might be explained by the discrepancy in study design, subject's characteristics and study sample size. In this study, we found a gender difference in the association between dietary GI and abdominal obesity. These observations were in line with earlier results reported from a prospective cohort study, in which a high-GI diet was associated with higher body weight, body fat and waist circumference in women, but not in men [13]. The reasons of this gender discrepancy are unknown, but it has been suggested that men may be less susceptible to the adverse effects of a high dietary GI than are women [13].

We found no significant association between dietary GI and general obesity. In line with this observation, among Spanish adult's population, no association between dietary GI and BMI was found [10]. In contrast, in a cross-sectional study by Lau et al., dietary GI was positively linked with BMI after adjustment for potential confounders [28]. Similar findings were reported from Japan [29] and US [30]. In a case–control study in Italy, dietary GI was inversely associated with BMI and waist to hip ratio [31]. Such inverse associations were also reported from other areas [32,33]. Study design, subject's characteristics, study sample size and lack of controlling for several confounders may in part explain these differences.

We found no significant association between dietary GL and general as well as abdominal obesity. In agreement with our results, findings from a cohort study on Spanish university graduates revealed no significant association between dietary GL and body weight [34]. In contrast, a cross-sectional study in Japan reported a positive association between dietary GL and overweight in children and central obesity in adolescents [12]. Despite this, some other studies reached an inverse association between dietary GL and obesity. For instance, in a cross-sectional study, the investigators concluded that, after energy-adjustment, dietary GL was inversely associated with BMI [10]. Likewise, in a study among older adults, dietary GL was inversely linked with visceral abdominal fat in men [35]. Compared with our study, these studies were conducted among children and older adults, had smaller sample sizes and had measured body composition data. Overall, given the conflicting findings, additional studies seem to be required to shed light on this issue.

The mechanisms through which dietary GI might influence on abdominal obesity are largely unknown. It has been proposed that high-GI diets may increase hunger and lead to overeating [36]. On the other hand, a low-GI diet decrease blood glucose and insulin response, increase satiety and decrease energy intake [37] and thus may prevent obesity.

Some strengths of this study are having a large sample size and consideration of the role of potential confounders in the data analysis. Several limitations also need to be considered. First, due to cross-sectional nature of this study, causal relationship between dietary GI and GL with general and abdominal obesity cannot be inferred. Therefore, further studies especially prospective studies are needed to confirm our findings. Second, although we controlled for several potential confounders, residual confounding cannot be excluded. In the current study, we used a validated FFQ for dietary assessment; however, measurement errors and misclassification of study participants cannot be avoided.

In conclusion, we found a positive association between dietary GI and abdominal obesity in women, but not in men. In addition, dietary GI was not associated with general obesity. No significant association was observed between dietary GL and general as well as abdominal obesity in either gender.

Conflict of interest

Authors declare that there is no conflict of interest.

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