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SHORT COMMUNICATION

Glycemic index and glycemic load in relation to body mass index and waist to hip ratio

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Abstract

Purpose High-glycemic index (GI) diet has been associated with obesity, but epidemiological data are inconsistent. We therefore investigated the relation between GI and glycemic load (GL) with body mass index (BMI) and waist to hip ratio (WHR), as a measure of body fat distribution.

Methods We analysed data from the control group of a network of hospital-based case–control studies from Italy. A total of 7,724 patients (3,482 men, 4,242 women; age range 18–82 years) were interviewed using a validated 78-item food-frequency questionnaire.

Results Mean BMI decreased from the lowest to the highest tertile of GI from 26.59 to 26.18 kg/m^2 in men ($p \sim 0.005$), and from 25.81 to 25.09 kg/m^2 in women ($p < 0.001$). With respect to GL tertiles, the corresponding values were 26.41 and 26.25 kg/m^2 in men ($p \sim 0.51$), and 26.01 and 24.93 kg/m^2 in women ($p < 0.001$). Using linear regression models including terms for major potential confounding factors and energy intake, GI and GL were inversely related to BMI: the coefficients (for the highest compared to the lowest tertile) were −0.46 among men and −0.81 among women for GI, and −0.79 and −1.33 for GL. No consistent association was found with WHR.

Conclusions GI and GL were, if anything, inversely related to BMI and WHR in this Italian population.

Keywords Glycemic index · Glycemic load · Obesity · Body mass index · Waist to hip ratio · Overweight

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Introduction

Glycemic index (GI) is a measure of the glucose response to ingestion of a fixed amount of available carbohydrates; glycemic load (GL) combines the qualitative and quantitative measures of carbohydrates and is the product of the GI and the amount of carbohydrates consumed. High-GI diet has been positively associated with obesity in adult rats, but epidemiological studies in humans so far have been inconsistent [1, 2]. Several cohort studies provided descriptive data reporting inverse relations between GI and body mass index (BMI), but these were generally focused on other outcomes [2]. With regard to GL, most studies indicated that GL is either unrelated or inversely related to BMI [2–5]. Only a few studies investigated GI and GL in relation to waist to hip ratio (WHR) and waist circumference (WC) [3, 6, 7], again showing inconsistent results.

To further investigate the relation between GI and GL with BMI and WHR as a measure of body fat distribution which is related to various chronic conditions [8], we analysed data from the control group of a network of hospital-based case–control studies on several cancer sites conducted in Italy [9–11].

Materials and methods

Subjects were 7,724 patients (3,482 men, 4,242 women, median age 57, range 18–82 years), admitted between 1991 and 2007 to a network of hospitals in six Italian areas for a wide spectrum of acute, non-neoplastic conditions, unrelated to known risk factors for common cancers, and to long-term diet modifications. Twenty-four per cent of subjects were admitted for traumas, 30% for other orthopaedic conditions, 18% for acute surgical, and 28% for other miscellaneous disorders. Less than 4% of subjects approached refused to be interviewed.

Trained interviewers interviewed subjects during their hospital stay using a standard questionnaire, including information on age, education and other sociodemographic characteristics, anthropometric measures (including height and habitual weight 1 year before hospital admission), occupational and leisure-time physical activity, lifestyle habits (notably tobacco smoking and alcohol drinking), a problem-oriented personal medical history, and family history of cancer. Anthropometric measures were available for 3,473 men and 4,222 women. Circumference of waist (2 cm above the umbilicus) and hip (at the maximal protrusion) were measured by interviewers on 2,530 men and 3,138 women.

An interviewer-administered food-frequency questionnaire (FFQ), with satisfactory reproducibility [12] and validity [13], was used to assess the participants' habitual diet during the 2 years prior to hospital admission. This included 78 foods, food groups or recipes most commonly consumed in the Italian population. Subjects were asked to indicate the average weekly frequency of consumption for each dietary item. Intake of total energy and selected nutrients was computed using an Italian food composition database [14, 15]. Fibre was defined as non-starch polysaccharides plus lignin.

We expressed GI as a per cent of the glycemic response elicited by white bread as a standard food primarily using international nutritional tables [16]. In order to take into account Italian cooking habits (e.g., pasta 'al dente'), Italian sources were used for a few local recipes [17]. Food items for which a GI had not been determined were assigned to the GI of the nearest comparable food (e.g., tangerines were assigned the GI of oranges). For each subject, we calculated average daily GI, by summing the products of the carbohydrate content per serving for each food or recipe, times the average number of servings per week, times its GI, all of which were divided by the total weekly carbohydrate intake [16, 18, 19]. A score for the daily average GL was similarly computed, but without dividing by the total amount of carbohydrates. Thus, each unit of GL represents the equivalent of 1 gram of carbohydrate from white bread. For these calculations, we used the carbohydrate content of 50 foods or recipes, since the remaining 28 foods or recipes (chiefly meat- and fish-based foods and cheese) contained a negligible amount of carbohydrates [15].

Body mass index was computed according to Quetelet's index (weight/height^2, kg/m^2). WHR was calculated as the ratio of waist on hip circumferences.

Statistical analysis

To estimate the relations of BMI and WHR with dietary GI and GL, we used linear regression models, separately among men and women. Since these associations were not always linear, the independent variables GI and GL were used as dummy variables (corresponding to tertiles). After examining crude associations, we also computed models including categorical terms for age (5-year groups), study centre, education (<7, 7–11, ≥ 12 years), occupational physical activity (low, intermediate, heavy activity), alcohol consumption (non-drinkers, 1–2, ≥ 3 drinks/day), tobacco smoking (never, ex smokers, current smokers of 0–14, ≥ 15 cigarettes/day), fibre intake (in quintiles) and energy intake (in quintiles) without alcohol and carbohydrates. Models further adjusted for fat and protein were also considered. We also repeated the analyses after excluding diabetics and obese (BMI $\geq$ 30 kg/m^2) subjects.

Results

Table 1 shows the characteristics of men and women by tertiles of GI and GL. Both men and women in the highest tertile of GI were younger and less educated than those in the lowest tertile; men reported a higher level of physical activity, while women a lower level. No distinct pattern emerged for GI in relation to alcohol drinking, tobacco smoking, and fibre and energy intakes, with the exception of a reduced intake of fibre with increasing levels of GI among women. The distribution of education and physical activity according to tertiles of GL were similar to those among tertiles of GI level, except for level of physical activity that was unrelated to GL among women. The proportion of current drinkers among women increased with increasing levels of GL. For both genders, tobacco smoking had a balanced distribution across tertiles of GL, whereas fibre and energy intakes increased with higher GL levels.

Body mass index tended to decrease with increasing GI and GL: mean BMI decreased from 26.59 in the lowest, to

Table 1 Characteristics of 3,482 men and 4,242 women according to tertiles of glycemic index and glycemic load. Italy, 1991–2007

Tertiles	Men				Women			
	I	II	III	P^f	I	II	III	P^f
Glycemic index								
Upper cut-off points	73.4	78.1	–		71.3	76.1	–	
Mean[a]	69.0 ± 3.9	75.8 ± 1.4	81.6 ± 2.9		66.7 ± 4.4	73.8 ± 1.3	79.7 ± 2.9	
N^b	1160	1154	1168		1421	1417	1404	
Age (mean, years)	59 ± 10	58 ± 11	58 ± 11	0.001	57 ± 11	57 ± 12	55 ± 12	<0.001
High education level[c] (%)	21.0	19.7	16.1	0.002	17.7	15.5	14.7	0.034
High physical activity[d] (%)	40.2	40.6	45.0	0.017	18.3	16.0	16.0	0.095
Current drinkers (%)	85.5	87.9	83.3	0.128	58.4	61.1	57.9	0.79
Current smokers (%)	33.2	32.5	33.8	0.75	20.4	18.5	22.1	0.27
Fibre intake (mean, g/day)	17.6 ± 5.9	17.6 ± 5.7	17.2 ± 5.7	0.11	17.4 ± 6.5	16.8 ± 5.6	15.5 ± 5.5	<0.001
Energy intake (mean, kcal/day)[e]	1114 ± 408	1152 ± 392	1145 ± 431	0.07	988 ± 357	1020 ± 350	998 ± 348	0.040
Glycemic load	184.7 ± 57.9	231.9 ± 63.3	297.0 ± 103.8	0.001	152.3 ± 54.8	192.5 ± 57.7	230.7 ± 79.2	<0.001
Body mass index (mean, kg/m^2)	26.59 ± 3.57	26.19 ± 3.29	26.18 ± 3.45	0.005	25.81 ± 4.34	25.34 ± 4.31	25.09 ± 4.47	<0.001
Waist to hip ratio (mean)	0.953 ± 0.085	0.944 ± 0.068	0.953 ± 0.079	0.019	0.832 ± 0.075	0.837 ± 0.071	0.833 ± 0.071	0.20
Glycemic load								
Upper cut-off points	193.4	259.7	–		156.5	211.5	–	
Mean[a]	153.4 ± 29.8	225.2 ± 18.8	335.8 ± 80.6		121.8 ± 26.7	182.7 ± 15.1	270.3 ± 59.5	
N^b	1159	1168	1155		1413	1412	1417	
Age (mean, years)	60 ± 10	59 ± 10	56 ± 11	<0.001	58 ± 11	56 ± 11	55 ± 12	<0.001
High education level[c] (%)	22.5	17.0	17.2	0.001	16.5	16.4	15.0	0.29
High physical activity[d] (%)	38.0	41.4	46.6	<0.001	17.1	15.4	17.8	0.64
Current drinkers (%)	85.0	87.2	84.5	0.74	52.9	59.7	64.8	<0.001
Current smokers (%)	33.5	31.6	34.5	0.62	21.2	20.8	19.1	0.16
Fibre intake (mean, g/day)	13.8 ± 4.4	17.3 ± 4.5	21.3 ± 5.8	<0.001	13.0 ± 4.5	16.4 ± 4.4	20.4 ± 6.2	<0.001
Energy intake (mean, kcal/day)[e]	904 ± 288	1127 ± 332	1381 ± 447	<0.001	781 ± 260	983 ± 262	1241 ± 359	<0.001
Glycemic index	71.7 ± 5.7	75.4 ± 4.5	79.4 ± 4.7	<0.001	69.8 ± 6.5	73.7 ± 4.9	76.7 ± 4.9	<0.001
Body mass index (mean, kg/m^2)	26.41 ± 3.49	26.29 ± 3.40	26.25 ± 3.44	0.51	26.01 ± 4.61	25.32 ± 4.16	24.93 ± 4.30	<0.001
Waist to hip ratio (mean)	0.959 ± 0.086	0.950 ± 0.069	0.942 ± 0.077	<0.001	0.838 ± 0.075	0.836 ± 0.072	0.829 ± 0.070	0.017

[a] Mean daily glycemic index or glycemic load ± standard deviation

[b] The sum does not add up to the total because of some missing values

[c] More than 11 years of education

[d] Occupational physical activity, more than 7 h per week

[e] Energy intake without alcohol and carbohydrates

[f] For categorical variables, Cochran–Armitage test for trend; for continuous variables, one-way ANOVA

Table 2 Multiple-regression-derived coefficients (β) and 95% confidence intervals (CI) of body mass index (BMI) and waist to hip ratio (WHR) on glycemic index and glycemic load among 3,482 men and 4,242 women. Italy, 1991–2007

	BMI (kg/m^2)				WHR			
	Men ($n = 3{,}473$)[a] (26.32 ± 3.44)[b] β (95% CI)	P	Women ($n = 4{,}222$)[a] (25.42 ± 4.38)[b] β (95% CI)	P	Men ($n = 2{,}530$)[a] (0.950 ± 0.078)[b] β (95% CI)	P	Women ($n = 3{,}138$)[a] (0.833 ± 0.072)[b] β (95% CI)	P
Glycaemic index								
I	Referent		Referent		Referent		Referent	
II	−0.43 (−0.71, −0.15)	0.002	−0.47 (−0.78, −0.16)	0.003	−0.009 (−0.0016, −0.001)	0.020	0.004 (−0.002, 0.010)	0.18
III	−0.46 (−0.74, −0.19)	0.001	−0.81 (−1.13, −0.49)	<0.001	−0.000 (−0.007, 0.007)	0.99	0.001 (−0.005, 0.007)	0.77
Glycaemic load								
I	Referent		Referent		Referent		Referent	
II	−0.49 (−0.79, −0.19)	0.002	−0.71 (−1.05, −0.37)	<0.001	−0.004 (−0.012, 0.004)	0.32	−0.003 (−0.009, 0.004)	0.43
III	−0.79 (−1.14, −0.45)	<0.001	−1.33 (−1.73, −0.94)	<0.001	−0.004 (−0.013, 0.005)	0.42	−0.009 (−0.017, −0.002)	0.019

Controlled for age, study centre, education, occupational physical activity, alcohol consumption, tobacco smoking, fibre intake, and energy intake without alcohol and carbohydrates

[a] The sum does not add up to the total because of some missing values

[b] Mean ± standard deviation

26.19 in the intermediate and to 26.18 kg/m^2 in the highest tertile of GI in men ($p \sim 0.005$), and from 25.81, to 25.34 and to 25.09 kg/m^2 in women ($p < 0.001$, Table 1). With respect to GL, the corresponding values were 26.41, 26.29, and 26.25 kg/m^2 in men ($p \sim 0.51$), and 26.01, 25.32, and 24.93 kg/m^2 in women ($p < 0.001$). Mean WHR was 0.953, 0.944, and 0.953 from the lowest to the highest tertile of GI in men ($p \sim 0.019$), and 0.832, 0.837, and 0.833 in women ($p \sim 0.20$). With respect to GL, mean WHR decreased from 0.959 to 0.950 and to 0.942 from the lowest to the highest tertile in men ($p < 0.001$), and from 0.838 to 0.836 and to 0.829 in women ($p \sim 0.017$).

Table 2 gives the regression coefficients of BMI and WHR on GI and GL. GI and GL were inversely related to BMI among both sexes. The coefficients for the second and the third tertile compared to the lowest one of GI were −0.43 and −0.46 among men, and −0.47 and −0.81 among women. Corresponding values for GL were −0.49 and −0.79 among men, and −0.71 and −1.33 among women. Similar estimates were obtained including in the models terms for fat and proteins. Similarly, no meaningful difference was observed without adjustment for energy intake or with adjustment for leisure physical activity instead of or in addition to occupational physical activity. After excluding 367 subjects with diabetes, the coefficient of BMI for the highest compared to the lowest tertile of GI was −0.45 (95% CI −0.73, −0.16) among men, and −0.80 (95% CI −1.12, −0.48) among women. Corresponding values for GL were −0.77 (95% CI −1.12, −0.41) and −1.32 (95% CI −1.72, −0.91). After excluding 1,081 obese subjects, the coefficient of BMI for the highest compared to the lowest tertile of GI was −0.31 (95% CI −0.53, −0.09) among men, and −0.72 (95% CI −0.96, −0.49) among women. Corresponding values for GL were −0.47 (95% CI −0.75, −0.20) and −0.84 (95% CI −1.13, −0.54).

No association with WHR was found for GI and GL, with the exception of a weak inverse association between GL and WHR among women (β for the highest compared to the lowest tertile = −0.009; $p \sim 0.019$) (Table 2). As for BMI, results were similar when fat and proteins were included in the models and when models were not adjusted for energy intake. The results for WHR were consistent after excluding diabetic and obese subjects.

Discussion

Although blood glucose fluctuation and consequent hyperinsulinemia would support the hypothesis of a positive relation between dietary GI and obesity [1], our findings did not confirm this association. GI and GL were, if anything, inversely related to BMI and WHR in this Italian population.

In line with our results, inverse associations between GI or GL and obesity [2–4] were reported in other studies, including another cross-sectional study in a Mediterranean population [4]. In that study, including 8,195 Spanish adults aged 35–74, the energy-adjusted mean difference in BMI between the highest and the lowest GL tertile was -0.43 kg/m^2 for men and -0.71 kg/m^2 for women after excluding underreporters [4]. In our study, GI was inversely related to BMI also when estimates were not adjusted for energy intake. This suggests that high-GI foods do not prompt one to eat more to reach satiety, as it has been suggested [20]. An earlier report from the present study [21] and a Greek investigation [22] also provided evidence that carbohydrate-rich diets were not positively associated with BMI in Mediterranean populations.

Among other measures of obesity, in the EURODIAB IDDM Complications Study [6], a lower dietary GI was associated with lower WHR and WC in 1,458 European men with type 1 diabetes, but no relation was found in 1,410 women. Likewise, WHR was inversely related to GI and GL in the 7,321 Whiteall II participants aged 39 to 63 among men (5,198), but not among women [3]. Another cross-sectional study on 979 adults with normal and impaired glucose tolerance from the Insulin Resistance Atherosclerosis Study reported no relation for GI and GL with either BMI or WC [7]. We further investigated WC in relation to a high-GI or GL diet, and found inverse associations also further adjusting for height. However, these associations disappeared after adjustment for BMI.

Other studies found positive relations between GI, GL, and obesity [1, 2, 23]. Possible heterogeneity in carbohydrates types and intakes in various populations may in part explain these differences, but long-term trials would be needed to further investigate the issue. The few small or short-term intervention studies in humans focusing on GI or GL and body weight change conducted so far again reported mixed results [20, 24].

Our results should be interpreted with caution due to a possible effect of underreporting of carbohydrate intake, especially among people with a high BMI who may selectively reduce—or underreport—refined carbohydrate intake [2]. Such an underreporting may account, at least in part, for the apparent inverse relation between GI and GL and BMI, as suggested by the attenuation of the coefficient estimates when we excluded obese subjects. Anthropometric measures were also self-reported, and it is known that self-reported height tends to be overestimated and weight underestimated, thus leading to a systematic underestimation of BMI, which tends to be grater on obese subjects [25–28]. There is no indication, however, that such underestimation of BMI is different across strata of diet, and specifically of GI and GL. Any such bias is unlikely therefore to have materially influenced our regression estimates.

This study was cross-sectional, thus limiting inference on the time sequence of the associations. However, it also has several strengths, including its large sample size, the virtually complete subjects' participation, and the availability of information from a detailed and validated FFQ [12, 13]. The study was not population-based, and disease status may have affected dietary and anthropometric data. However, we excluded subjects admitted to hospital for chronic conditions leading to long-term modifications of diet. Moreover, since mean GI and GL in our data were similar to values reported in other Italian studies [29], we are confident that our sample was largely unbiased with reference to exposure measures.

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