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Methodology for adding glycemic index and glycemic load values to 24-hour dietary recall database

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Abstract

Objectives—We describe a method of adding the glycemic index (GI) and glycemic load (GL) values to the nutrient database of the 24-hour dietary recall interview (24HR), a widely used dietary assessment. We also calculated daily GI and GL values from the 24HR.

Methods—Subjects were 641 healthy adults from central Massachusetts who completed 9067 24HRs. The 24HR-derived food data were matched to the International Table of Glycemic Index and Glycemic Load Values. The GI values for specific foods not in the table were estimated against similar foods according to physical and chemical factors that determine GI. Mixed foods were disaggregated into individual ingredients.

Results—Of 1261 carbohydrate-containing foods in the database, GI values of 602 foods were obtained from a direct match (47.7%), accounting for 22.36% of dietary carbohydrate. GI values from 656 foods (52.1%) were estimated, contributing to 77.64% of dietary carbohydrate. The GI values from three unknown foods (0.2%) could not be assigned. The average daily GI was 84 (SD 5.1, white bread as referent) and the average GL was 196 (SD 63).

Conclusion—Using this methodology for adding GI and GL values to nutrient databases, it is possible to assess associations between GI and/or GL and body weight and chronic disease outcomes (diabetes, cancer, heart disease). This method can be used in clinical and survey research settings where 24HRs are a practical means for assessing diet. The implications for using this methodology compel a broader evaluation of diet with disease outcomes.

Keywords

Glycemic index; 24-hour dietary recalls; Nutrition

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Introduction

The concept of the glycemic index (GI) has provided the scientific community with a new way to examine the quality of carbohydrate (CHO), which has been useful in research on the etiology and prevention of diabetes, coronary heart disease, obesity, prostate cancer, and other chronic diseases [1–6]. Historically, CHOs have been classified into two major forms: complex and simple. Monosaccharides, and disaccharides are simple CHOs. Polysaccharides are complex CHOs and include starch, cellulose, fiber, and related compounds. A defect of this classification scheme has been its inability to predict plasma glucose and insulin responses [7], which are critical factors in the genesis of many health outcomes.

The GI, developed by Jenkins et al. [8] in 1981, allows the comparison between CHO foods on the basis of their physiologic effects rather than on their chemical composition. The currently accepted physiologic method [9] for determining the GI value of a food is to feed at least 10 healthy subjects 50 g of digestible (available) CHO from the test food and then measure the effect on their capillary blood glucose levels over the next 2 h. The area under the 2-h blood glucose response curve (glucose AUC) for each person for this food is then derived. On a separate occasion, test subjects consume a 50-g portion of a reference food (white bread or glucose) and their 2-h capillary blood glucose response is again measured for the corresponding AUC. A GI value for the test food is then calculated for each person by dividing that person's glucose AUC for the test food by the glucose or white bread AUC for the reference food. The final GI value for the test food is the average GI value for all subjects [8,10]. This ranking of CHO-containing foods according to the glycemic response has proved to be uniquely useful to our understanding of the effect of particular types of CHO on health [1,11,12].

Importantly, different foods containing equal amounts of CHO can produce a wide range of glycemic responses in comparison with the average blood glucose response of a referent food [9]. The effect of CHO on blood glucose and insulin concentrations is determined primarily by the amount of CHO consumed (quantity) and the rate of absorption (quality). Glycemic response and the subsequent determination of GI values are influenced by factors beyond type of CHO, such as fat, protein, fiber, and nutrient composition of the food. Cooking and other processing methods contribute to further variation in the response. In general, foods with a low degree of starch gelatinization or with a higher level of soluble fiber have slower rates of digestion and therefore lower GI values [11].

The glycemic load (GL) is determined by the combined effect of quality and quantity per serving of CHO ingested from a particular food. The GL is the GI of a food multiplied by its CHO content in grams. GI and GL are thus closely related, but they represent different ways to evaluate the response to a CHO-rich food. GL reflects a food's physiologic effect better than the amount of CHO or the GI alone [13].

Although many researchers have applied GI estimation values to dietary assessment instruments [14–17], the methodology used to obtain these values has only recently been documented in detail in a few studies using the food frequency questionnaire (FFQ) [17–19]. However, although similar, description of methodology in assigning GI values in 24-hour dietary recalls (24HRs) is currently lacking. The objectives of the present study are to describe the methods used to establish the GI and GL from an extensive set of 24HRs and to calculate overall dietary GI and GL. The database of foods comes from the 24HRs collected from a healthy population in central Massachusetts, as part of the Seasonal Variation of Blood Cholesterol Levels (SEASONS) study, in which we also examined variations of GI and GL and then associations with body weight and blood lipids using 24HRs [20–23]. This documentation will help to continue the effort to establish a consistent methodology to add GI

values to dietary assessment tools and may result in greater use of the GI in research and clinical care.

Materials and methods

Dietary assessment

The 24HRs were collected by trained dietitians using the Nutritional Data System (NDS), which was developed and is maintained by the University of Minnesota's Nutrition Coordinating Center (NDS DOS versions 2.6, 2.7, and 2.8) [24]. CHO-containing foods (individual and mixed dishes) were then re-entered into a more current version of NDS (NDS 5.0_35 for Windows), which provides greater depth of analysis, specifically on types of CHO (i.e., glucose, fructose, sucrose), types of fiber (soluble or insoluble), and fat content. NDS provides 136 nutrients and food components (such as phytoestrogens and carotenoids) for analysis on more than 18 000 foods in the database. All foods from the physiologically tested and published International Table of Glycemic Index and Glycemic Load Values (International Table) [9] and University of Sydney online databases (<http://www.glycemicindex.com>) were subsequently entered into the same NDS system to facilitate nutrient correlations with study foods. Detailed food preparation methods and portion sizes were systematically collected as part of our study. This allowed for better estimation of GI and enabled GL calculation on an individual level.

Estimation of GI and GL

Available data were derived from 9067 24HRs providing information on a total of 1482 different foods. Because the GI is based on foods that contain CHO, we used the NDS nutrient analysis program to exclude food items without CHO, leaving a total of 1261 CHO-containing food items for analysis in the SEASONS study.

The next step involved matching our foods directly to those in the International Table and/or the updated University of Sydney online database (the same investigators established both). The international Table provides GI averages from studies that tested foods for physiologic response and geographical location, whereas the University of Sydney online database provides additional detail as to the population in which the food was tested (normal, diabetic, or metabolic syndrome), the reference for who performed the testing, average GI values from each study, and the duration of the testing (2 or 3h). All foods from the International Table or the online database that were matched to our foods were analyzed through NDS to provide a standard platform of comparison. It should be noted that NDS provides a breakdown of total CHO including fiber, whereas the International Table is based on available CHO (with total fiber content subtracted). This is one of the reasons that all foods from the International Table used in comparison with those in the present study were first analyzed through NDS.

It also was deemed important to match foods to those in the International Table by selecting the food with best geographic and botanical matches, when that information was available, and to consider food preparation methods (addition of other ingredients, cooking time, etc.) that are described as part of the collection of the 24HR. If more than one study performed physiologic testing and was included in the International Table, GI values of the pertinent botanical and geographic studies were averaged to arrive at the established GI.

The International Table and the University of Sydney databases are excellent sources of information but not an exhaustive listing of all foods and corresponding GI values. In particular, these databases do not contain many of the foods from our 24HRs of American foods. Thus, each food not found in the International Table [9] had to be matched to a similar food. In a simple example that highlights only types of sugars (one of the factors in determination of the

GI), consider Pepsi, with ~27 g of total CHO per 250-mL serving, containing ~41% fructose (GI 19), ~37% glucose (GI 100), ~20% sucrose (GI 68), and ~0.9% maltose (GI 105). Pepsi is a “best match” to beverages in the International Table and then to Coca Cola, which also has ~27 g of the same percentages of these types of CHO per 250-mL serving. Coca Cola has a GI value of 63; this then becomes the assigned GI value for Pepsi. This is a much better match than to a similar beverage, Fanta, which has ~32 g of total CHO per 250-mL serving, with ~18% fructose, ~17% glucose, ~62% sucrose, and 0.8% maltose and a GI value of 68.

Similar foods were determined by ingredient breakdown. First, the nutritionist (B.C.O.) estimated which foods from the International Table or online database should be compared with our dataset. Second, portion size was standardized between foods, which were then matched as follows: total CHO was broken down into sugars as described by the example above, and fiber content was characterized and compared (soluble versus insoluble, amylose versus amylopectin). Further consideration for matches assessed fat content, acidity, particle size, protein, and cooking and processing methods. NDS provides in-depth analysis of most nutritional factors such as fat and fiber that allow for close links to similar foods in the International Table or online database. In general, foods with a low degree of starch gelatinization or with a higher level of soluble fiber have slower rates of digestion and absorption and therefore lower GI values [11]. Some factor information (acidity, particle size, amylose:amylopectin ratio) was obtained through food science references [25–28]. Our study's foods that were not matched directly to foods in the International Table and University of Sydney online database were matched to the available foods listed there with similar characteristics, as described above, to achieve estimates of GI value. The nutritionist made final determinations based on all available information and from subjective experience and knowledge of foods.

Mixed dishes represented an interesting challenge because the evaluative process involved breaking down ingredients of the mixed dish to consider direct or similar matches of individual ingredients. NDS was employed for nutrient calculation and composition, with attention to type of CHO such as sucrose, fructose, glucose, food preparation methods, and other GI factors (i.e., fiber, fat, acid). Using the same analytical techniques described above, the ingredients were then matched to tested foods in the International Table or the University of Sydney online database. We assigned the GI for each ingredient, by calculating the overall GI according to a weighted average of the GI values of each food, based on the proportion of the total CHO contributed by each food. [29].

There were three foods in the database unknown to us, and for which there was not enough information to establish a GI value, because the early version of NDS that was used for the original collection did not supply enough nutrient information. These foods are no longer commercially available and are not in the current version of NDS. These three foods, listed in the early version of NDS as “Second Nature,” “Figurines,” and “Sego Lite,” contributed little to the CHO consumption in our study and were omitted from the final analysis.

There was a small number of different commercial sugar cookies ($n = 13$) for which an average GI value was assigned. These 13 foods were grouped together with an average GI for the group, rather than assessed individually as we did with the rest of the foods. This was done because the early version of NDS was unable to provide sufficient data to allow analysis through the current NDS database. We had to select the GI value based on macronutrients and fiber rather than on specific types of CHO and food preparation techniques. All 13 of these foods were processed foods, likely to contain refined CHO, and were assigned values commensurate with similar cookies or digestives in the International Table and University of Sydney online database.

Confidence in estimations

Two nutritionists with a master's degree were involved with assignment of GI values in this study. Each nutritionist doing estimations assigned a subjective quality control confidence level, ranging from 1 to 5, to each food's GI resolution. Blinded to previous estimations, this estimate was redone by each nutritionist before running results from the analysis, and approximately 10% of the foods were adjusted after further analysis. Because we did not do direct testing of the foods themselves, a level of 5 (100% confident of GI value) was not achieved. A value of 4 was assigned if the food had a direct match (same food) to the International Table, a value of 3 if the food was closely related to a food in the International Table or online database (matched on GI factors and nutrient information), a value of 2 if the food was lacking a close match on one of the GI factors, and a value of 1 if the food was assigned an average GI value for the group of foods, rather than matching on individual GI factors and nutrient information (such as the 13 types of cookie). Of 1261 foods, 1160 (91%) achieved a level of ≥ 3 .

Calculation of daily GI and GL

The recommended formulas [30] for the calculation of daily GL and GI are as follows:

$$\text{Overall Dietary GL} = \sum_{i=1}^n \text{GI}_i \times \text{CHO}_i$$

$$\text{Overall Dietary GI} = \sum_{i=1}^n \text{GI}_i \times \text{CHO}_i / \sum_{i=1}^n \text{CHO}_i$$

where GI_i is the GI for food i , CHO_i is the CHO content in food i (grams per day), and n is the number of foods eaten per day. The NDS program provided the CHO content of foods necessary for GL calculation. The GI value for the food was multiplied by 1.43 to convert from glucose to white bread as the referent GI value [9].

Results

The average caloric intake calculated from the 9067 24HRs was 1966 kcal/day (SD 569), the percentage of calories from CHO was 51 (SD 7.5), and the daily intake of CHO was 247 g (SD 74). Study participants were mostly European American, middle-aged, and overweight; men and women were equally represented, and subjects were predominantly non-smokers. Table 1 lists subjects' general characteristics.

In total, 1261 CHO-containing foods were identified from the 9067 24HRs from the SEASONS study. GI values of 602 foods were obtained from direct matches (47.7%), which accounted for 22.36% of dietary CHO. GI values from 656 foods (52.1%) were estimated, contributing to the remaining 77.64% of estimable dietary CHO. The GI values from three foods (0.2%) could not be assigned; these three foods contributed little CHO. A confidence level of 4 (direct match with food in table) was assigned to 602 foods (48% of total), a confidence level of 3 (close match) was assigned to 558 foods (44% of total), a confidence level of 2 was assigned to 85 foods (6.7% of total), 13 foods were assigned a confidence level of 1 (1%), and 3 foods (0.2%) were unable to be assigned (and therefore dropped from analyses). The average daily GI was 84 (SD 5.1, white bread 100) and the GL was 196 (SD 63). The distribution of GI for the SEASONS study population is shown in Figure 1.

Table 2 lists the top 20 CHO sources of the SEASONS participants. For ease of comparison with other studies, the categories of white rice (3.71% of CHO) and potatoes (3.50% of CHO), which have a range of GI values depending on the particular variety of rice or potato, were

collapsed into the average GI value for rice or potatoes, respectively. These top 20 foods accounted for 48% of CHOs consumed from all 1261 foods. Table 3 lists the top 20 highest GI foods and the frequency of consumption by this population. Interestingly, the foods with the highest GI values were not necessarily frequently consumed (cornstarch 0.44%, an ingredient added as a thickening agent with a GI of 159, and dehydrated potatoes 0.35%, with a GI of 134). The top 20 foods with the highest GLs are listed in Table 4. The ranking of these foods is quite similar to the top 20 CHO foods, indicating that CHO, and not GI ranking, had the greatest influence on GL in this population.

Discussion

This report describes our methods of estimating the GI, which determined our calculations of the overall GI and GL in our study. The clinical utility of the GI as a method of blood glucose control remains in question, because the American Diabetes Association (ADA) primarily recommends CHO counting for blood glucose control, although recognizing that several GI factors influence the glycemic response to foods [31,32] and that GI and GL may have additional benefit. It is noted in the ADA position paper that integration of the GI as a primary method of glycemic control is quite complex when it is applied to mixed foods and mixed meals. The GI is not currently labeled on American food products and only recently has the GI begun to appear on European labels. Although physiologic testing is the standard for establishing GI values, this testing is performed reputably in only a few places, and it is costly and time consuming. Therefore, it may not be within the range of many researchers and clinicians to consider.

Our methods are consistent with those described in three recent publications. Flood et al. [18] described a similar methodology in applying matching and estimation to the National Cancer Institute Diet History Questionnaire Database, a food frequency dietary assessment instrument. Neuhouser et al. [19] described their methods used for adding the GI to the FFQ used in the Women's Health Initiative, recognizing the importance of methodology in GI estimation. Using a semiquantitative 114-item FFQ, Schulz et al. [17] also briefly described their methods in assigning GI. There are many studies that have examined the association of GI and GL with disease, but few studies (using FFQ or 24HR) have mentioned their methods of GI estimation; those that explained methods did so only in a cursory fashion as part of a summary description, and not as the main focus of the paper [17]. The studies by Flood et al. and Neuhouser et al. are among the first to describe in detail the steps they used to determine GI values for their FFQ database. It is important that researchers are consistent in the methodology of assigning GI values to dietary assessment instruments. This will improve the evaluation of GI and any association with chronic disease, and it will assist with utilization of GI and GL in clinical and research settings.

We chose the 24HR for estimation of the GI for several reasons. The FFQ includes a short list of predefined food items and food groups (both with standardized portions and totaling about 60–150 food items), and queries about average diet over a specified period in the recent past (usually 3 mo to 1 y). Nutrient scores are derived from comparison with a standard portion size multiplied by the frequency of food consumed. The groupings of foods inherent in the design of an FFQ may, and probably do, represent a wide range of GI values. The actual consumption of the study population of particular foods within categories is not known, and because of its semiquantitative nature, the precise portion size eaten is unknown. It is inherent in the nature of FFQs that average GI values must be assigned to a grouping of foods that may actually have wide ranges of GI values and would be expected to vary considerably from person to person. However, both dietary assessment methods have their place; the FFQ is much less expensive to administer than 24HRs, and the methodology for determining the GI in FFQ can be accomplished as described by Flood et al. and Neuhouser et al. Because of the practical utility

of FFQs in large cohort studies, few 24HRs have been tested for this purpose [14,33]. The 24HR can be used as validation of the FFQ in this dimension, in a manner similar to that of nutrient comparison [34–36].

The GI is developed to measure CHOs consumed with respect to glycemic effect; calculation of GL is based on knowledge of specific food items, in combination with the portion size and CHO content of each food item consumed. Therefore, the GL based on multiple 24HRs may be more accurate with regard to the actual food consumption of individuals and populations than that based on the FFQ. Using this methodology in the context of 24HR is important per se (because it is a practicable assessment method in clinical research). It also has added relevance because the 24HR is often the referent method in validation studies of structured questionnaires including the FFQ [37–39], and it is reasonable to consider GI or GL as a parameter for which to test in validation.

Although the GI has been determined for several FFQs, its use in the 24HR is only rarely documented. Recently, two studies have established the GI from 24HRs [14,33]. Davis et al. [33] reported that 44% of foods were best-matched to the International Table on CHO profiles, 33% were matched to similar foods based on CHO profiles, and 23% were matched to a range average of similar foods. Davis et al. summarized their methods of GI estimation (they ran their foods through the NDS as we did), but the main focus of their report was not to describe the methods of estimation. Our study results showing a mean daily GI of 84 were close to the estimation of Davis et al. who reported an average daily GI of 89 in an elderly population. We have listed estimated GI and GL values in comparison with other populations and studies in Table 5.

There were several limitations in our methodology. First, we acknowledge that our source of estimation of the GI, the International Table and online databases, may be subject to error in GI values, including within-subject and between-laboratory variations. However, Wolever et al. [40,41] demonstrated that, if the recommended physiologic methods were used, the results of GI agreed reasonably well (i.e., $\pm 5\%$). In addition, because each subject's glycemic response to a given food is standardized to that subject's glycemic response to the reference food, this effectively takes between-subject variation out of the equation. Second, data collected using this early version of NDS were incomplete for some foods in terms of nutrient data available, preparation methods, and brands. Subsequent versions of NDS have improved tremendously, but still fall short of capturing all the factors influencing the determination of the GI of any particular food. If the GI is to become clinically useful, this additional information will have to be made widely available (eventually appearing on food labels and in the NDS database) and methods of determination must be standardized. Third, although the NDS has an excellent database of individual items, there are still many items that may be missed (although we encountered few such foods in this study).

In addition, the International Table (and in Europe and Canada) total CHOs contain only digestible CHOs, whereas the NDS is a United States–based nutritional data system, and subsumes soluble and insoluble fiber under total CHO. This is an important reason to standardize the analysis platform (running all foods compared through the same analytical software) to arrive at our estimations. Other studies that have described methodology have also emphasized the importance of this consideration [17–19].

Our study population consisted largely of white, middle-class people who were mostly members of a health maintenance organization. The study protocol involved a lengthy series of clinic visits and diet assessments, and participants were likely to have been relatively motivated. For these reasons, although our methods of GI determination may be used in a

variety of studies, our dataset of foods may not be fully generalizable to other socioeconomic strata and to other cultures and ethnic groups.

Conclusion

This is the first study that describes a methodology for adding GI and GL into a 24HR-derived database, the most widely used dietary assessment method used in large nutritional surveys, such as the National Health and Nutrition Examination Survey. We believe that describing and understanding methods to estimate the GI will increase the research and clinical utility of the GI and GL and help to standardize the GI estimation for those studies relying on dietary assessment tools.

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Fig 1.
Distribution of glycemic index from the Seasonal Variation of Blood Cholesterol Levels study population.

Table 1
Demographic information of SEASONS study participants ($n = 641$)*

Age (y)	47.14 $\pm$ 12.27
Gender	
Male	331 (52%)
Female	310 (48%)
Education:	
High school or less	158 (25%)
Some college/associate's degree	240 (38%)
Bachelor's degree or higher	240 (38%)
Smoking status:	
Smoker	111 (18%)
Non-smoker	515 (82%)
BMI (kg/m ²)	27.33 $\pm$ 5.42

BMI, body mass index; SEASONS, Seasonal Variation of Blood Cholesterol Levels.

* Data are presented as mean $\pm$ SD or numbers (%) of patients.

Table 2
Primary sources of carbohydrate from top 20 contributors

Food	%Total carbohydrate	Cumulative % total carbohydrate	Glycemic index (white bread as referent)
All-purpose flour	6.84	6.84	100
White sugar	4.72	11.56	97
Cola beverage	3.96	15.52	91
White bread	3.89	19.41	100
White rice	3.71	23.12	92
Boiled potato, without skin	3.50	26.62	100
Macaroni	2.91	29.53	67
Orange juice	2.81	32.34	76
Bagel	2.21	34.55	102
Banana	1.93	36.48	73
Carbonated beverage, non-cola	1.50	37.98	97
Roll, hamburger	1.41	39.39	100
Sugar, confectioner's (powdered)	1.28	40.67	97
Bread, whole wheat, mixed grain	1.19	41.86	74
Tea, hot or iced with sugar	1.10	42.96	97
Apple, fresh with skin	1.05	44.01	57
Bread, Italian	1.03	45.03	100
Beer or ale, regular	0.96	45.99	—
Milk, 1% fat	0.96	46.95	46
Muffin, English	0.96	47.91	110

Table 3
Top 20 highest GI foods and frequency of consumption

Food	GI (white bread as referent = 100)	Frequency of consumption (%) *
Cornstarch	159	0.4399
Dates, dried	147	0.0245
Pancake mix	146	0.0510
Syrup, table; corn, maple-flavored	142	0.1989
Candy, fruit bars and fruit chews	142	0.003
Parsnips, cooked	139	0.0013
Cream of rice cereal	136	0.0007
Potatoes, dehydrated	134	0.3478
Cereals, dry, Kix	132	0.0046
Cereals, dry, total	132	0.0007
Cereals, dry, corn flakes (Kellogg's)	132	0.0591
Fruit bar, commercial	129	0.0020
Cereals, dry, Rice Chex	127	0.0186
Oatmeal, instant, fortified	124	0.0003
Oatmeal, instant, apple cinnamon	124	0.0013
Hostess Twinkie, all flavors	124	0.0046
Cereals, dry, Life cinnamon	124	0.0007
Oatmeal, instant, maple and brown sugar	124	0.0026
Cereals, dry, Crispix (Kellogg's)	124	0.0088
Oatmeal, instant, cinnamon spice	124	0.0010

GI, glycemic index

* Each occasion a food is consumed counts separately. For example, if a subject consumed a piece of white bread at breakfast in addition to a glass of milk, at lunch a hamburger on a white bun with a glass of milk, and at dinner had pasta, Italian bread, and a glass of milk, the total foods counted are white bread (3), milk (2), hamburger (1), and pasta (1). Therefore, the frequency of consumption for white bread would be $(3/7) \times 100$, or 42.9%.

Table 4

Top 20 highest GL foods

Food	Total GL	Cumulative of total GL
All-purpose flour	15.87	15.87
White sugar	10.64	26.51
White bread	9.02	35.53
White rice	7.91	43.44
Cola beverage	8.28	51.72
Potatoes, without skin	7.81	59.53
Bagel	5.27	64.08
Orange juice	4.66	69.46
Macaroni	4.54	74.00
Carbonated beverage, non-cola	3.39	77.39
Banana	3.27	80.66
Roll, hamburger	3.27	83.93
Sugar, confectioner's (powdered)	2.89	86.91
Potatoes, dehydrated	2.89	89.89
Syrup, table; corn, maple-flavored	2.84	92.73
Tea, hot or iced with sugar	2.48	95.21
Muffin, English	2.44	97.65
Bread, Italian	2.38	100.03
Bread, whole wheat, mixed grain	2.05	102.08
Roll, white dinner	2.00	104.08

GL, glycemic load (white bread as referent).

Table 5

A summary of GI and GL values from the literature

Study	Mean or median $\pm$ SD			Population source	Mean age (y)	Males (n)	Females (n)	Dietary assessment method
	GI [*]	GL	CHO [†]					
Present study	84 $\pm$ 5.1	196 $\pm$ 63	247 $\pm$ 74	641 healthy adults in central Massachusetts	47	331	330	24HR
Neuhouser et al. [19]	71.5 $\pm$ 7.2	140.1 $\pm$ 78.7	—	WHI	Postmenopausal women	0	100 in sample from observation arm	FFQ
McCarl et al. [‡]	85.1 $\pm$ 5.5	169.6 $\pm$ 32.4	—	Iowa Women's Health Study	61.7	0	35 197	FFQ
Nielsen et al. [§]	85 $\pm$ 6.9	220 (10-y-old girls) to 310 (16-y-old boys)	—	European Youth Heart Study	10 and 16	404	445	24HR and quality food record
Liu ^{//}	81.3	141.8	—	NHANES III	44.8	6825	7082	FFQ
Dominique and Liu [¶]	—	119	155	Nurses' Health Study, 1976	45.5	0	88 802	FFQ
Liu et al. [2]	77	161	186	Nurses' Health Study, 1984	50.5	0	75 521	SFFQ
Jonas [#]	74	115	155	Cancer Prevention Study II, Nutrition Cohort	40–87	0	97 787	FFQ
Liu ^{**}	75 $\pm$ 5	166 $\pm$ 32	221 $\pm$ 36	Women's Health Study, 1993	59	0	244	SFFQ
Liu ^{††}	75 $\pm$ 4	147 $\pm$ 23	198	Nurses' Health Study, 1990	63	0	280	SFFQ
Forst ^{‡‡}	86 $\pm$ 5	—	—	Survey of British Adults, 1986–1987	39.9	699	721	7-d food record
Liese et al. [16]	82.94 $\pm$ 5.72	183.47 $\pm$ 79.94	220.5 $\pm$ 92.4	Insulin Resistance Atherosclerosis Study	54.8	442	537	FFQ
Amano et al. ^{§§}	92 $\pm$ 9	215 $\pm$ 53	—	Weight-reduction program at municipal health center in Tokyo	52.5	0	32	3-d food record at beginning of program
Scaglioni et al. ^{////}	82.94 $\pm$ 2.86	207.35 $\pm$ 52.91	300 $\pm$ 66	Randomly selected healthy at-term singleton births during second half of 1991 at one institution	8	60	45	FFQ
Schulz et al. [17]	82.94	183.04	234.8	Insulin Resistance Atherosclerosis Study	54.9	467	604	FFQ

24HR, 24-h dietary recall interview; CHO, carbohydrate; FFQ, food frequency questionnaire; GI, glycemic index; GL, glycemic load; NHANES III, National Health and Nutrition Examination Survey III; SFFQ, Semi-Quantitative Food Frequency Questionnaire; WHI, Women's Health Initiative

* GI referent is white bread = 100.

- [†] One gram of CHO = 4 kcal.
- [‡] Cancer Epidemiol Biomarkers Prev 2006;15:892–6.
- [§] Br J Nutr 2005;94:992–7.
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- ^{††} Am J Clin Nutr 2001;73:560–6.
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